California
Hospital Outcomes Project

Heart Attack Outcomes
1996 -1998
Volume 2: Technical Guide

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Report on Heart Attack Outcomes in California, 1996-1998

Office of Statewide Health Planning and Development

California Hospital Outcomes Project

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This volume represents the Office of Statewide Health Planning and Development's first hospital outcomes report produced by an in-house team. It draws upon the expertise of four new staff members, Steven Lubeck, Ph.D., Victor Simon, Yuan Qing (Cliff) Li, M.P.H., and Louise Hand, and benefits from Andra Zach's and Mary MacDonald's prior collaboration with university-based researchers on earlier reports.

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Overview

Report on Heart Attack Outcomes in California: 1996-1998

The California Hospital Outcomes Project is an initiative mandated by the State of California, and conducted by the Office of Statewide Health Planning and Development (OSHPD), to develop public reports comparing hospital outcomes for selected conditions treated in hospitals throughout the state.

The Report on Heart Attack Outcomes is intended to encourage all California hospitals to improve their care and give credit to the hospitals that are the leaders. It can also help insurers, employers, and consumers to select hospitals based on quality of care.

The California Hospital Outcomes Project

Heart attack (acute myocardial infarctions or AMIs) was chosen as one of the first conditions to be reported upon by the California Hospital Outcomes Project because it is important, common, and deadly. Every year approximately 40,000 heart attack patients are admitted to 400 California hospitals. More than 5,000 of these persons die.

The mortality rates published in previous heart attack reports have been used in many ways. Hospitals have used their results to evaluate and improve their quality of care. Payers have used the reports to contract with the best hospitals. Consumers have used the reports to make more informed decisions.

The results published in this report are useful because:

- **They have been risk-adjusted.** Patient age, gender, type of heart attack, and chronic diseases were used to adjust for differences in patient risk when calculating hospital mortality rates.

- **They have been validated.** A major validation study involving nearly 1,000 heart attacks at 30 hospitals showed that variations in how hospitals report their data to OSHPD do not significantly affect their risk-adjusted death rates. In general, low-mortality hospitals treat heart attacks more aggressively than high-mortality hospitals.

Content of the Report on Heart Attack Outcomes

This report is the most recent in a series that began in 1993. This report includes heart attack cases from 1996 through 1998. It incorporates improvements in the risk-adjustment methodology introduced in previous reports, including:

- linking with Vital Statistics records to ascertain deaths occurring outside the hospital;
- refining certain patient risk-factor definitions based on the findings of the validation study published in 1996; and
- using six months of pre-heart attack hospital records to more completely describe patient risk factors.

This report consists of four volumes:

The **User's Guide** (Volume 1) is intended for all those interested in hospital performance including hospital staff, employers, government agencies, health plans, and insurance companies. This volume provides a brief description of the study background and methods. It also contains two Tables that display the results for individual hospitals based on heart attacks that occurred between 1996 and 1998.

The **Technical Guide** (Volume 2) is intended for health services researchers, health care providers, and others interested in the statistical methods used to calculate risk-adjusted death rates.

The **Detailed Statistical Results** (Volume 3) contains the numerical results for individual hospitals upon which the classifications in the User's Guide are based. In addition, there are Tables that aggregate the results to the county level. It also contains a graphical representation of both individual hospital and county-wide results, which can be used to examine annual trends.

The **Hospital Comment Letters** (Volume 4) is intended to give readers of the Report on Heart Attack an appreciation of its strengths and weaknesses from the hospitals' perspectives.

To obtain these volumes of the report contact:

Office of Statewide Health Planning and Development
Healthcare Information Resource Center
818 K Street, Room 500
Sacramento, CA 95814
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The report volumes are also available on the internet at
http:\\www.oshpd.state.ca.us

Hospitals were provided with a *Hospital Guide to Using the Report Data* several weeks before the *Report on Heart Attack Outcomes* was published. This document accompanied each hospital's patient-specific data. Hospitals used this document to access and use their patient-specific data and to prepare their comment letters, provided in Volume 4. More importantly, hospitals and their physicians can use this information to target areas where heart attack care might be improved.

Section

1

Using this Guide

The Technical Guide is intended for health services researchers, health care providers, and others interested in the statistical methods used to calculate risk-adjusted mortality rates.

Technical Guide Overview

This volume of the Report on Heart Attack Outcomes provides background information about the risk-adjustment models used to derive hospital-specific results for acute myocardial infarction (AMI). These risk-adjustment models were developed through a multi-step process, explained in detail in the 1997 *Technical Guide,* that involved reviewing the scientific literature, convening an expert panel, developing criteria for including and excluding cases, identifying adverse outcomes, selecting risk factors, estimating statistical models, refining and testing these models, and calculating risk-adjusted outcome measures for heart attacks reported between 1991-1993. This report does not revise or redevelop the original models described in this *Technical Guide*, but, based on the most current heart attack data, follows the format of the previous report in re-estimating the parameters for all predictors.

The details of the process used to develop the original models are described in the *Report on Heart Attack 1991-1993* Volume 2 Chapter 2: Literature Summary, and Chapter 8: Procedure for Developing Risk-Adjustment Models. The referenced report may be found on OSHPD's website at www.oshpd.state.ca.us/hpp/chop/hearatck.htm. These details may help others replicate the results or apply the methods to other regions. While the research team believes the models developed and used in the California Hospital Outcomes Project are as good as possible given the available time, resources, and data, suggestions for improvement are welcome.

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Section 2

Selection Criteria

The AMI analysis was designed to focus on fresh[1] AMI admissions to acute care hospitals in California. The goal was to select patients who had just experienced an acute heart attack due to coronary artery disease. Inclusion and exclusion criteria were developed after careful review of the medical literature and extensive discussions with an expert panel that included cardiologists, health services researchers, a cardiac care nurse, and a health information management professional. This report includes AMIs admitted to California hospitals between January 1, 1996 and December 1, 1998. The previous AMI report included AMIs admitted between January 1, 1994 and December 1, 1996.

Inclusion Criteria

AMI cases were identified by reviewing the discharge abstracts from all acute care hospitals in California that report data to the Office of Statewide Health Planning and Development (OSHPD). These hospitals do not include facilities operated by the U.S. Department of Veterans Affairs or the Department of Defense. Discharge abstracts that were identified as patients discharged from a non-acute level of care (e.g., skilled nursing, rehabilitation) were not reviewed.[2] Cases selected for the study were required to meet all four of the inclusion criteria listed below.

1. **A principal diagnosis of acute myocardial infarction, initial or unspecified episode of care (410.x0 or 410.x1), or a principal diagnosis of a presumed AMI complication with a secondary diagnosis of AMI, initial or unspecified episode of care.**

   The principal diagnosis is "the condition established, after study, to be chiefly responsible for occasioning the admission of the patient to the hospital for care.[3] Note that cases with a principal diagnosis of 410.x2 (AMI, subsequent episode of care) were not included because the focus was on fresh admissions requiring urgent diagnosis and management. Cases with a principal diagnosis of 410.x0 (AMI, unspecified episode of care) were included because analyses for previous AMI reports found they were clustered at certain facilities and their overall mortality rate and other characteristics closely resembled 410.x1 cases (AMI, initial episode of care). These facilities appear to be improperly coding some initial AMI hospitalizations as 410.x0.

[1] For the purposes of this report, "fresh" is defined as the first presentation for a new AMI.

[2] Before January 1, 1995, hospitals were not required to submit separate reports (or bundles of discharge abstracts) for each type of care they provide. For example, in 1993, 81 of 210 hospitals did not report their skilled nursing patients separately and 44 of 88 hospitals did not report their rehab patients separately.

[3] OSHPD, 1991. Discharge Data Tape Format Documentation.

Table 2.1 lists the principal diagnoses that were presumed to represent AMI complications. At some hospitals, patients who presented with one of these cardiovascular complications were assigned a principal diagnosis of AMI and a secondary diagnosis of the observed complication. At other hospitals, the complication was coded as the principal diagnosis because coders failed to appreciate the temporal sequence. To capture similar cases from both sets of hospitals, patients with principal diagnoses of suspected AMI complications were included in the sample. Cases with other principal diagnoses were not included because their AMIs may have resulted from unrelated conditions. Several conditions that appeared on the list of acceptable principal diagnoses in the first two AMI reports, such as arterial thrombosis, hypotension, and complete atrioventricular block were removed because OSHPD's validation study suggested that AMIs in these patients are often secondary to other conditions or procedures, such as arterial bypass surgery, sepsis, and conducting system disease, respectively.

Although coding guidelines allow respiratory failure (518.81-518.82) to be coded as the principal diagnosis when it follows an AMI, it was not included on the list of allowable principal diagnoses because analyses for previous reports indicated most such cases had an indeterminate infarction site and an underlying diagnosis of pneumonia or chronic obstructive pulmonary disease. These findings suggest that AMIs more often were complications rather than causes of respiratory failure.

2. **Age at admission of 18 years or greater.**

   Children were not included because the pathophysiology of AMI in this population usually relates to a congenital anomaly or an acute ischemic event rather than coronary artery disease.

3. **Site of care at the source of admission equal to home (1), residential care facility (2), ambulatory surgery (3), other (nonacute) inpatient hospital care (6), prison/jail (8) or other (9).**

   Patients admitted from long-term care (4), acute inpatient hospital care (5), or newborn (7) were excluded.

4. **Date of admission between January 1, 1996 and December 1, 1998 (inclusive).**

   As described in Section 3, the encrypted social security number and date of birth were used to link prior and subsequent records for each case. Cases admitted from December 2 through December 31, 1998 were excluded because discharge records after December 31, 1998 were not available when this study was conducted. Therefore, 30-day outcomes were unknown for some of these cases. Note that the admission date was always used for case selection because it most closely approximates the actual date of the AMI.

Record Linkage

Records for patients transferred from one hospital to another within California were linked (as described in Section 3). Linkage was used to combine multiple records on the same patient into a single episode of care. This means that information from a series of discharge abstracts for a patient transferred from one facility to another was combined, and the disposition of the final hospitalization (e.g., death or survival) was ascribed to the "index" hospital. The "index" hospital was the first facility in a series of linked transfers that reported a **qualifying** AMI admission (based on the above inclusion criteria). That admission was labeled the "index" AMI, and need not have been the first admission in the transfer series.

The purpose of this procedure was to eliminate differing transfer rates as a cause of outcome differences across hospitals, and to accumulate as much information as possible about each AMI case. A strategy was developed to maximize the number of correct matches and to minimize the number of erroneous matches. This strategy is described in Section 3.

Exclusion Criteria

Finally, several exclusion criteria were defined to eliminate cases that may not truly represent fresh AMIs, such as unstable angina that was potentially misdiagnosed by physicians or misinterpreted by coders. Because the index record alone was not always sufficient to establish the presence or absence of these exclusion criteria, they were applied after linkage. Cases with any of the following characteristics were excluded:

1. **One or more prior AMI admissions within the 8 weeks preceding the index AMI admission.**

   An AMI was excluded from the study if it was preceded by a **prior AMI admission** within 8 weeks (from admission date to admission date). Prior AMI admissions were defined by a principal or secondary diagnosis of 410.x0 or 410.x1, without regard to the patient's age, source of admission, or type of care, or to other inclusion and exclusion criteria listed in this Section. For example, an AMI that occurred in a skilled nursing or intermediate care facility would not have been eligible for this study, but would have counted as a prior AMI and thereby disqualified any AMI admission during the next 8 weeks. An AMI in a patient admitted for gallbladder disease would not have been eligible for this study (because it might have been a postoperative complication), but still would have counted as a prior AMI.

   This exclusion is important for two reasons. First, many patients are admitted for acute management of an AMI, then go home and return to the hospital several weeks later for diagnostic evaluation or coronary revascularization. *The International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) directs coders to classify any AMI less than eight weeks old as acute (410.xx), although it offers a fifth

digit to distinguish the initial episode of care from subsequent episodes. If prior AMI admissions had not been sought, the same AMI might have been inadvertently double-counted. It is also important to identify prior AMIs because some people suffer a second AMI very shortly after their first, and these reinfarcts confer an increased risk of death. Such reinfarcts had to be excluded to obtain a relatively homogeneous sample of AMIs.

Note that a prior AMI did not disqualify an index AMI if the patient was transferred from the prior facility to the index facility (e.g., the two records were part of a transfer series). By definition, the index AMI in a transfer series was the first record that met the four inclusion criteria listed above. In addition, a prior AMI did not disqualify an index AMI if the prior AMI record was actually part of a separate transfer series (or "episode of care") that started with another index AMI admission outside the 8 week prior interval.

2. **Total length of stay less than 2 days (i.e., 0-1 day) with an ultimate discharge disposition other than: same acute hospital (2); other acute hospital (5); against medical advice (10); or death (11).**

   Note that the ultimate disposition is the one reported on the last in a series of linked records, if a patient was transferred from one facility to another. The total length of stay in this situation was calculated by adding the lengths of stay across hospitals.

   Short hospitalizations were thought to represent remote infarctions, trivial infarctions (e.g., cardiac enzyme elevation without electrocardiographic changes), or patients who actually "ruled out" for AMI--with the exception of deaths, inter-hospital transfers, and discharges against medical advice (all of which had artificially truncated hospital stays). The clinical advisors unanimously agreed that a hospital stay of two or more days remains the standard of care for fresh AMIs in California. ICD-9-CM guidelines require coders to assign the AMI code (410.xx) to the diagnosis of "rule out" myocardial infarction, unless an alternative diagnosis has been established.[4] Previous research has confirmed that patients discharged with a diagnosis code of 410.xx after a short stay often ruled out for AMI or were admitted for post-AMI diagnostic evaluation.[5] Other investigators have excluded short-stay patients for the same reason.[6]

3. **An external cause-of-injury (E) code indicating a transport accident of any type (E800.x-E848) from the index record or any subsequent linked record.**

   These cases were excluded because of concern that traumatic myocardial contusions, which usually result from steering column impact, may be

[4] Coding Clinic for ICD-9-CM 1985; 2(2):3.

[5] Iezzoni, LI, Burnside S, Sickles L, Moskowitz MA, Sawitz E, Levine PA. Coding of acute myocardial infarction: Clinical and policy implications, Annals of Internal Medicine 1988; 109:745-751.

[6] Udvarhelyi IS, Gatsonis C, Epstein AM, Pashos CL, Newhouse JP, McNeil BJ. Acute myocardial infarction in the Medicare population. Process of care and clinical outcomes. JAMA 1992; 268:2530-2536.

misclassified as AMIs. Traumatic injury can lead to elevated cardiac enzymes and electrocardiographic changes that mimic those seen in acute infarction.

Table 2.1: ICD-9-CM codes for principal diagnoses presumed to represent AMI complications if the case had a secondary diagnosis of 410.x0 or 410.x1

ICD-9-CM Code	*ICD-9-CM Description*
427.1	Paroxysmal ventricular tachycardia
427.41	Ventricular fibrillation
427.42	Ventricular flutter
427.5	Cardiac arrest
429.5	Rupture of chordae tendinae
429.6	Rupture of papillary muscle
429.71	Acquired cardiac septal defect
429.79	Other sequelae of myocardial infarction
429.81	Other disorders of papillary muscle
518.4	Acute edema of lung, unspecified
780.2	Syncope and collapse
785.51	Cardiogenic shock, without mention of trauma

Section 3

Linking Hospitalization and Death Records

Record linkages are important for several reasons. First, linkages with subsequent hospital discharge abstracts and death certificates help identify patients' outcomes (e.g., death within 30 days). Otherwise, hospitals that transfer or prematurely discharge their sickest AMI patients might have unduly low death rates. Second, linkage makes it possible to identify fresh AMIs as described in Section 2. Third, linkages provide important information about clinical risk factors. Diabetes and other comorbidities are not always coded on discharge abstracts, so more complete information can be obtained when multiple records are available. Finally, hospital discharge records are linked to Vital Statistics records to determine deaths that occur outside the hospital within 30 days of admission.

Linking Hospitalizations

This section describes the linkage methods developed for the acute myocardial infarction (AMI) study. The goal of this linkage process is to identify relevant hospital discharge abstracts, order them temporally, and create a linked single-record analysis file summarizing information from all related abstracts.

Step 1. Identify records that meet initial selection criteria

The first step in record linkage was to create a condition file containing all records that: (1) met preliminary inclusion criteria, and (2) were within the time window used to select cases. These preliminary inclusion criteria are described in Section 2. The window period included admissions between January 1, 1996 and December 1, 1998 (inclusive). This search generated 139,678 records, which became candidates for study. Note that many of these candidate records were excluded or relabeled as prior or transfer admissions, after the additional steps described below.

Step 2. Find all additional records with linkage potential

This step is used to find any additional records within the study period that might link with the AMI records identified in Step One, within a relevant time frame. For AMI cases, the relevant time frame was eight weeks prior to admission for an AMI to one day after the discharge date.

First, invalid social security numbers (SSNs) were identified in three ways and set to missing: (1) SSNs with certain repetitive patterns that hospitals use to designate missing values (i.e., 111-22-3333); (2) SSNs associated with multiple hospital admissions where the dates of birth differ; and (3) SSNs outside the valid values provided by the Social Security Administration.

Next, the AMI condition file was divided into two subfiles. The largest subfile contained 134,261 records with valid SSNs; the second subfile contained 5,417

records that lacked SSNs but did have other information useful for linkage (e.g., date of birth, gender, zip code).

Two lookup files were constructed from the largest AMI condition subfile. These lookup files were used to search for other records within the study time frame (e.g., prior or transfer hospitalizations) that might be related to the AMI records already identified. Lookup file 1 contained one entry for each unique SSN. Each entry specified all of the admission dates and birth dates associated with that SSN. No SSN was associated with more than two birth dates. This file contained 121,139 records, after deleting 313 duplicate records and collapsing 12,501 records where a single SSN had two or more AMIs.

Lookup file 2 contained one entry for each unique combination of birth date, gender, and 5-digit zip code; it had 121,552 records after deleting 11,472 duplicate records and 1,234 records with invalid demographic data. This file was used to search for additional records related to candidate records without an SSN. If records in the master files matched this lookup file, the record was pulled and the associated SSN (if available) was assigned to the condition file record lacking an SSN.

The lookup files were used to locate all potential records for the study. This process involved four steps:

2.1 Using lookup file 1, all records with an exact SSN match were extracted from the OSHPD master files, if at least two of three birth date elements (i.e., month, day, year) also matched (or if one element matched and the other two were transposed). If an SSN in the lookup file was associated with two different birth dates, both birth dates were checked as potential matches for a candidate record. Birth dates were used to confirm linkages because of the danger of improperly linking records that appeared to have the same SSN because of a data entry error. This step found an additional 261,992 records with matching SSNs.

2.2 Lookup file 2 was matched against the AMI condition subfile that contained records without SSNs. An exact match was required on birth date, gender, and 5-digit zip code. Records in the condition file that lacked SSNs but matched entries in the lookup file were assigned the SSNs associated with those entries. As a result, SSNs were assigned to 373 of the 5,417 records that lacked SSNs but had other data elements useful for linkage. This left 5,044 records with a valid birth date, gender, and zip code, but without an SSN.

2.3 In a final effort to determine SSNs for the remaining 5,044 residual records, each was matched against the OSHPD master files using birth date, gender, and 5-digit zip code. An additional 424 matching records were pulled from the master files. Of these 424 matching records, 134 had valid SSNs.

2.4 A total of 42 unique SSNs were found and assigned to AMI cases in Steps 2.2 and 2.3. These SSNs were then used to pull an additional 81 matching records from the OSHPD master files. The remaining 5,334 cases in the residual file without a valid SSN were assigned a simulated SSN. As described in Step 4, cases without valid SSNs were not linked to other hospital admissions.

Step 3. Delete Duplicate Records and Resequence Record Sets

The files created in Step 2 above were combined and sorted by recoded SSN, admission date, discharge date, date of birth, gender, OSHPD facility number, total charges, length of stay, diagnosis-related group (DRG), and number of diagnoses. The purpose of sorting by these variables was to identify exact duplicate records from the same hospital. This sort identified 53 duplicate records that were deleted.

The remaining records were then separated into two files containing AMIs with: (1) only one hospital admission during the study period (N=39,980), and (2) multiple admissions (N=348,326). The multiple admission file was then sorted to identify records from the same hospital that matched on SSN, admission date, discharge date, date of birth, and gender, but differed on DRG, total charges, or discharge disposition. No records were identified as problematic after this sort.

Finally, 36 pairs of acute-care records with the same SSNs and admission and discharge dates, but from different hospitals, were manually reviewed. These patients were apparently admitted to one acute care hospital, transferred to another, and then discharged, all on the same day. Each set was manually sequenced based on the discharge disposition and admission source. Any record with a disposition of "death" was sequenced last. Any record with a disposition of "general acute care hospital" was sequenced first.

Step 4. Order Records in the Period Around the Admission

All records for a given SSN were extracted in Step 2, including some admissions that were irrelevant to the AMI study. For example, a person treated for AMI could have been admitted several months later for appendicitis. The goals of Step 4 were to define the periadmission period, consisting of the index AMI admission and the records around it, and to delete irrelevant records. This was done in four steps: (1) the index admission was identified; (2) transfer records were identified; (3) prior admissions were identified; and (4) the periadmission number was assigned.

Index Admissions. The first step in defining a periadmission period was to identify the index AMI record, according to the inclusion criteria described in Section 2. At this point, some admissions and their subsequent transfers or readmissions were marked for exclusion, as described in Section 2.

Transfers. The next step was to identify transfer records. Very specific criteria were established to classify subsequent hospitalizations as transfers.

These criteria were necessary because most hospitalizations after AMI relate to evaluation or surgical therapy of coronary artery disease and do not belong to the periadmission period. Subsequent skilled nursing facility/intermediate care facility (SNF/ICF) admissions also do not belong to the periadmission period. Some patients experienced several transfers during the periadmission period; the last transfer represented the outcome record (as long as it occurred within 30 days of the AMI). The specific criteria used to identify transfers were:

4.1 Records with a "report type" of skilled nursing and intermediate care (3), psychiatric care (4), alcohol/drug care (5), or rehabilitation care (6) were excluded. Step Two pulled many records that were not from general acute care hospitals. These were used to identify prior admissions, but were not used to identify transfers.

4.2 Records with a "report type" of general acute care (1) were categorized according to the discharge disposition of the record immediately prior to the index AMI, and included or excluded as follows:

a. Other care (03) or long-term care (04) within this hospital, or long-term care (07), residential care (08), or prison/jail (09). No subsequent records were linked.

b. *Other care* (06) or *Other* (13). OSHPD's 1988 reabstraction study[7] showed that some cases reported to have this discharge disposition were actually transfers to acute care hospitals (02). Therefore, subsequent records were linked when: (1) the admission date was the same as the preceding discharge date; and (2) the hospital identification number was different from that on the preceding record (suggesting that the patient may have remained at the same level of care); and (3) the principal diagnosis on the candidate transfer record was neither rehabilitation (V57.xx) nor psychiatric (290.x-319).

c. *Acute care in another hospital* (05). Some cases with this discharge disposition appear to have been transferred to lower levels of care. Therefore, subsequent records were linked only when: (1) the hospital identification number was different from that on the preceding record (suggesting that the patient may have remained at the same level of care); and (2) the admission date was up to one day later than the preceding discharge date (allowing for late night transfers), and (3) the principal diagnosis on the candidate transfer record was neither rehabilitation (V57.xx) nor psychiatric (290.x-319). When a patient was readmitted to an acute care hospital more than one day after a prior discharge, the second hospitalization was regarded as a separate episode of care and not a transfer.

d. Routine (01), acute care within same hospital (02), against medical advice (AMA) (10), or home health service (12). Some patients were

[7] Patient Discharge Data Section, Report of Results from the OSHPD Reabstracting Project: An Evaluation of the Reliability of Selected Patient Discharge Data, July through December, 1988, Sacramento, CA: California Office of Statewide Health Planning and Development, December, 1990.

discharged to home or left against medical advice and returned to a hospital later the same day. These patients were still in the acute phase of care when they were readmitted, so their hospitalizations needed to be linked. Subsequent records were linked only when: (1) the admission date was the same as the preceding discharge date; and (2) the principal diagnosis on the candidate transfer record was neither rehabilitation (V57.xx) nor psychiatric (290.x-319).

Prior Admissions. Next, all records that preceded an index AMI record but fell within the study frame were classified as prior admissions. Prior admissions were defined as an admission date up to 180 days before the index AMI admission. To be considered as a prior admission, a record must have a recoded SSN that matched on all nine digits, a recoded SSN found on either an index AMI or transfer record. Records were discarded if they were linked to index AMI or transfer records only by demographic variables (e.g., date of birth, gender, zip code).

Periadmission Period. All prior, index, and transfer admissions related to a single AMI were grouped into a periadmission period. A total of 193,041 records not flagged as prior, index, or transfer admissions were discarded.

After the multiple record file was ordered, it was recombined with the single-admission file from Step 3 to create the periadmission file. A new variable was created to group sets of records (prior, index, transfer) into distinct periadmission periods. This grouping variable was needed because some patients had multiple periadmission periods within the study frame. The periadmission file contained one-to-n periadmissions composed of one-to-n records for each SSN.

Step 5. Create the Linked Single-Record Analysis File

This step transformed the periadmission file into a linked analysis file containing one record per periadmission. The transformation began by running programs that used all clinical information from all records in the periadmission file to describe the frequency of all diagnoses and procedures, and their relationship to the study outcomes.

The periadmission file was then used as input for a complex program summarizing the diagnoses and procedures from prior, index, and transfer records into clinical risk factors, as described in Section 6.[8] Ethnicity and date of birth can be recorded differently from one record to another, and source of payment can change from one hospital to another. Therefore, index-record values for these variables were retained. After eliminating 1516 cases from hospitals with unusual coding (Section 5), the linked analysis file was ready for statistical modeling. The final analysis file included 128,509 AMIs, including 21,763 cases with prior admissions, and 106,746 cases with no prior admissions.

[8] Only variables from the index AMI admission can be returned to the index hospital for review and comment. The risk factor program flagged cases which required special handling for this reason. Two variables were created in the linked analysis file to count records labeled as prior admissions and transfers. If either variable was greater than zero, clinical risk factors that could have been obtained from prior or transfer admissions are set to missing in the file returned to hospitals.

Linking Death Certificates to Hospitalizations

In 1996, the California Hospital Outcomes Project staff at OSHPD began linking its Patient Discharge Data Set (PDDS) with the Department of Health Services' Vital Statistics (VS) or death certificate file. This linkage was designed to provide complete ascertainment of deaths up to 365 days after hospital discharge, with partial ascertainment of deaths up to two years after discharge (although only deaths within 30 days of an index AMI admission were counted in this report). Each death certificate was linked to all applicable records in the PDDS, but each PDDS record was linked to zero or one death certificates. The linkage was performed deterministically, following specific criteria and rules. Key elements of this linkage procedure are described below, but a more complete description is available upon request from OSHPD's Health Policy and Planning Division.

For this study, OSHPD Outcomes Project staff linked VS records to hospital discharges by searching sequentially for three types of linkages: (1) death certificates that matched perfectly on SSN, birthdate, gender, race, and 5-digit zip code; (2) death certificates that matched exactly on SSN, but not on all demographic variables; and (3) death certificates that matched exactly on birthdate, gender, race, and 5-digit zip code, but not on SSN.

OSHPD Outcomes Project staff did not search for "soft" linkages involving both SSN and demographic variables (e.g., a one-digit discrepancy on both SSN and date of birth). Among the second and third types of linkages, the degree of matching or mismatching were prioritized and labeled.

In this report, all patients with a discharge disposition of death (11) on either their index AMI admission or a linked transfer record within 30 days of admission were counted as deaths, regardless whether a matching death certificate was found. Similarly, any death certificate matched by the algorithm was automatically accepted as valid if an index or subsequent record had a discharge disposition of death within 30 days of the index AMI admission.

Based on previous analyses reported in the 1997 *Technical Guide*, there is little evidence of hospitals reporting AMI deaths that did not actually occur. Therefore, all vital statistics linkages established by OSHPD were accepted as valid if the patient's discharge disposition was reported as "death," either on the index AMI record or on any linked record within 30 days of the index AMI admission.

Among patients who were discharged alive according to PDDS data, a higher standard for vital statistics linkage was applied. The need for this higher standard was established through special analyses of two types of problematic matches reported in the 1997 *Technical Guide*. As a result of these analyses, the following minimum criteria were adopted for vital statistics linkage among patients who were discharged alive (according to the hospital record):

1. gender had to match exactly; and

2. SSN had to match partially or exactly (as defined above); and

3. birthdate had to match partially or exactly (as defined in Step 2.1 under "Hospital Discharge Linkage"). A birthdate match was defined as partial if at least two of three elements (i.e., month, day, last two digits of year) also matched, or if any one element matched and the other two were exactly transposed. This definition is slightly stricter than the definition applied by OSHPD to discard birthdate mismatches, but it is consistent with the definition that has been used to link PDDS records in the last three reports of the California Hospital Outcomes Project.

With these criteria, one can be nearly certain that if an AMI patient discharged alive from an acute-care hospital in California has a linking death certificate within 30 days of admission, that patient actually died after discharge.

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Section 4

Definition of Outcome

Only one outcome of acute myocardial infarction was studied: death within 30 days of admission. In selecting this outcome, several statistical and clinical issues were considered. For example, death is an important and rather frequent outcome of AMI hospitalizations. Medical interventions, such as prompt administration of intravenous thrombolytics, can reduce the risk of early death after an AMI. In addition, two recent studies of OSHPD data have shown that death is reported reliably. These characteristics make it a useful outcome for analysis.

Identification of Deaths

Deaths within 30 days of admission were determined using two different data sources: linked hospital discharge abstracts and vital statistics records (death certificates). Hospital discharge abstracts only record deaths that occur in nonfederal acute care hospitals in California. By contrast, a death certificate is generated whenever a California resident dies, regardless of where the death occurs. For the reasons described in Section 3, a death certificate cannot always be linked to previous hospital discharge abstracts for the same patient. Therefore, neither hospital discharge abstracts nor vital statistics records capture all 30-day deaths (i.e., those that occur within 30 days of an AMI).

Among 128,509 fresh AMIs hospitalized in California between January 1, 1996 and December 1, 1998, 12,670 deaths were reported as in-hospital within 30 days of admission from the master files.[9] Eighty-five additional in-hospital 30-day deaths were identified after linkage with vital statistics. Finally, 2,781 AMIs were discharged alive from the hospital, but identified as having died within 30 days of admission after linkage with vital statistics. All 15,536 deaths identified from these data sources were counted in this study. Compared to the 1994-1996 period included in the previous AMI report, statewide 30-day mortality decreased from 12.74 to 12.09 %.

In-hospital deaths beyond 30 days were not counted because these late deaths may have resulted from social problems or unrelated illnesses.[10] Not counting late deaths made the outcome comparisons across hospitals more valid. Other cutoffs were considered but the 30-day limit was adopted because it is consistent with previous research in the field.

[9] A total of 3,017 AMIs with a discharge disposition of death did not have a matching vital statistics death record.
[10] During 1996-1998, 129 patients with AMIs had in-hospital deaths more than 30 days after admission.

Attribution of Death

Because 21.0 % of AMI patients were transferred from the hospital where they were initially admitted to another acute care facility, it was important to define an "episode of care" that included all inpatient treatment for a single AMI. The outcome of each "episode of care" was attributed to the hospital that originally admitted the patient. Attribution of outcomes to the initial hospital is an important and desirable feature of this study. Otherwise, hospitals that transferred many of their AMI patients to other facilities would have had relatively low risk-adjusted mortality because some of their patients would have died elsewhere. Conversely, hospitals that neither transferred their own patients elsewhere nor accepted transfers would have had relatively high risk-adjusted mortality. These biases were avoided by attributing linked outcomes to the initial hospital. In addition, the risk of death is highest during the first 24 hours after an AMI and most of the key decisions that affect short-term mortality are made during this period. Determining whether, when, and where to transfer the patient is one of the most important of these decisions.

Section

5

Selection and Inclusion of Hospitals

Certain hospitals may not be directly comparable with the great majority of hospitals caring for AMI patients in California. For example, non-acute care hospitals are not organized and staffed to treat patients with acute conditions. Any AMI records from such hospitals are probably either miscoded or represent atypical patients. In addition, the data received from several acute care hospitals had important limitations that precluded evaluating these facilities. This section describes the hospitals eligible for study and the specific criteria used to exclude eligible hospitals.

Hospitals Eligible for Study

The original study sample included cases from all non-federal acute care hospitals in California, as noted in Section 2. Hospitals operated by the U.S. Department of Veterans Affairs or Department of Defense do not report data to OSHPD and therefore could not be included.

Criteria for Excluding Hospitals

Although hospitals devote considerable effort to producing accurate discharge abstracts, the guidelines that professional coders follow when they abstract medical records are sometimes ambiguous and subject to multiple interpretations. Hospitals also face financial incentives that affect how diagnoses are coded, particularly for Medicare beneficiaries. Consequently, the prevalence of various AMI risk factors is extremely variable across hospitals. Some hospitals reported these associated conditions on far fewer records than would be expected based on statewide prevalence data. If this variability reflects unusual documentation practices by physicians or coding practices by medical records personnel, it could seriously distort comparisons of risk-adjusted mortality across hospitals.

To avoid this problem, in a given year, hospitals with the most unusual data related to important clinical risk factors were excluded for that year. These exclusion criteria were applied to all linked records in a single "episode of care," because all such records were used to ascertain clinical risk factors. The criteria listed below were derived after reviewing the prevalence of every risk factor across hospitals, and considering possible reasons for excess variability. For example, the proportion of AMI patients with a history of coronary bypass surgery could vary widely because some hospitals specialize in treating complex patients. On the other hand, conditions such as hypertension and congestive heart failure should be distributed more evenly across hospitals.

Probability cutoffs identify hospitals where the prevalence of a risk factor was very significantly different from the statewide average, in a statistical sense.

However, they do not address the clinical plausibility of such differences. For this reason, fixed prevalence cutoffs were also established. Hospitals were excluded only if they exceeded **both** the probability cutoff and the fixed prevalence cutoff for a risk factor. These prevalence cutoffs represent the limits of clinical plausibility, based on literature review and discussion with specialists in the field. They were confirmed and slightly adjusted based on the empirical distribution of prevalences across hospitals.

Risk Factor	***Direction***	***Prevalence Cutoff***	***State Prevalence***
Subendocardial site	undercoded	12.0%	28.0%
Hypertension	undercoded	18.0%	45.9%
Other/unspecified site	overcoded	25.0%	6.3%
Congestive heart failure	undercoded	11.0%	31.8%

The combined effect of these criteria was to exclude 8 hospitals that admitted 261 AMI patients in 1996, 12 hospitals that admitted 747 AMI patients in 1997, and 9 hospitals that admitted 508 AMI patients in 1998. Table 5.1 lists the hospitals excluded from this study and provides the specific reason for their exclusion.

Hospitals were not excluded from this study if they reported heart attack cases for at least one of the three years included in the analysis. Table 5.2 lists the hospitals that were included in the study, but did not have eligible AMI discharges in at least one year. Reasons for reporting fewer than three years include:

- A hospital may have closed or opened during the three-year interval of this report;
- A hospital did not routinely treat AMIs, but may have occasionally done so on an emergency basis during one or two years.

If a given hospital consolidated with another hospital between 1996 and 1998 and stopped reporting to OSHPD using its original identification number, all of that hospital's discharges during the three-year interval were attributed to the hospital named in the consolidation.

Table 5.1: Hospitals excluded from AMI models in one or more study years

Hospital	*County*	*1996*		*1997*		*1998*	
		Cases	*Cause*	*Cases*	*Cause*	*Cases*	*Cause*
Biggs Gridley Memorial Hospital	Butte					22	c
Colusa Community Hospital	Colusa	20	a				
Coalinga Regional Medical Center	Fresno	6	c	10	c		
Selma District Hospital	Fresno	30	c				
General Hospital	Humboldt			39	c		
Pioneers Memorial Healthcare District	Imperial			59	d		
Good Samaritan Hospital	Kern			12	c	3	c
Ridgecrest Regional Hospital	Kern					46	d
Central Valley General Hospital	Kings	41	a,c	55	a,c	38	a,c
Coast Plaza Doctors Hospital	Los Angeles					30	a
LA Co/MLK/Drew Medical Center	Los Angeles	84	c	115	c	137	c
UC Irvine Medical Center	Orange					67	c
South Coast Medical Center	Orange			61	a		
Needles-Desert Communities Hospital	San Bernardino					40	d
UCSD/Medical Center - Thornton Hospital	San Diego			46	d		
UCSF - Mt. Zion	San Francisco					125	c
St. Luke's Hospital	San Francisco			101	c		
San Joaquin General Hospital	San Joaquin	57	b	73	b		
Siskiyou General Hospital	Siskiyou	16	c	12	c		
Emanuel Medical Center	Stanislaus			164	c		
Trinity Hospital	Trinity	7	c				

Cause for exclusion
a: Subendocardial site of infarction possibly undercoded
b: Hypertension possibly undercoded
c: Other or unspecified site of infarction possibly overcoded
d: Congestive heart failure possibly undercoded

Table 5.2: Number of cases in hospitals not excluded in one more study years, but reporting no eligible AMIs in one or two study years

Hospital	*County*	*1996*	*1997*	*1998*
Kaiser Foundation Hospital - Richmond	Contra Costa	1	1	0
Sanger General Hospital	Fresno	2	0	1
Kingsburg District Hospital	Fresno	0	0	1
Southern Inyo Hospital	Inyo	1	0	1
Thompson Memorial Medical Center	Los Angeles	23	8	0
Specialty Hospital of Southern California	Los Angeles	13	7	0
Lincoln Hospital Medical Center	Los Angeles	0	1	0
Long Beach Doctors Hospital	Los Angeles	4	0	0
Los Angeles Community Hospital	Los Angeles	12	0	0
Mission Community Hospital	Los Angeles	10	2	0
Orthopaedic Hospital	Los Angeles	0	0	1
Pioneer Hospital	Los Angeles	101	66	0
North Hollywood Medical Center	Los Angeles	97	87	0
SHC Specialty Hospital	Los Angeles	18	0	0
Westside Hospital	Los Angeles	7	0	0
Woodruff Community Hospital	Los Angeles	9	4	0
USC Kenneth Norris Jr. Cancer Hospital	Los Angeles	0	0	1
Los Angeles Co/Rancho Los Amigos National Rehab Ctr	Los Angeles	0	1	5
Kaiser Foundation Hospital – Baldwin Park	Los Angeles	0	0	29
Desert Palms Community Hospital	Los Angeles	17	0	0
Surprise Valley Healthcare District	Modoc	0	1	0
Modoc Medical Center	Modoc	0	4	2
Pacifica Hospital	Orange	33	24	0
Tustin Hospital and Medical Center	Orange	8	0	2
Plumas District Hospital	Plumas	2	4	0
Valley Plaza Doctors Hospital	Riverside	1	0	0
The Heart Hospital, Inc.	Riverside	0	0	4
Mountains Community Hospital	San Bernardino	0	2	1
Harbor View Medical Center	San Diego	21	6	0
San Joaquin General Hospital	San Joaquin	0	0	53
Santa Ynez Valley Cottage Hospital	Santa Barbara	0	1	2
Fairchild Medical Center	Siskiyou	0	6	15
North Coast Healthcare Center - Sotoyone Center	Sonoma	0	0	1
Del Puerto Hospital	Stanislaus	1	0	0
Stanislaus Medical Center	Stanislaus	52	42	0

Section 6

Definitions and Prevalence of Risk Factors

In this study, risk factors were defined as characteristics or conditions that probably existed at the time of admission and may have influenced patient outcomes. Three sets of risk factors were examined.

The first set includes demographic characteristics such as gender, race, and age. The second set includes hospitalization characteristics such as the source and type of admission. The third set represents clinical characteristics such as diabetes and cancer. These clinical factors include both chronic illnesses and conditions or procedures associated with the principal diagnosis (e.g., the portion of the heart involved in an AMI). All clinical risk factors were based on the diagnoses and procedures listed on discharge abstracts and coded using ICD-9-CM. Each patient discharge abstract includes a principal diagnosis and principal procedure, plus as many as 24 other diagnoses and as many as 24 other procedures.

Demographic and Hospitalization Characteristics

The demographic variables available from patient discharge abstracts are gender, race/ethnicity, and age. Table 6.1 summarizes these characteristics of the AMI sample. For analytic purposes, race/ethnicity was aggregated into four categories: White, African-American, Latino, and other.

Several measures describing the hospitalization were available from patient discharge abstracts: expected principal source of payment, source of admission, type of admission, and disposition. The first three of these variables were tested in risk-adjustment models, as described in Section 7. The expected source of payment was used as a crude indicator of socioeconomic status. The source of admission may help distinguish critically ill patients who are admitted through an emergency room from more stable patients who are admitted directly from a physician's office. The type of admission reflects whether a patient was sick enough to require admission to an intensive care unit. The large number of categories for expected source of payment and source of admission were aggregated into a smaller number of categories for analytic purposes. Table 6.2 summarizes the hospitalization characteristics of the AMI sample.

Criteria for Selecting Clinical Risk Factors

After reviewing the recent medical literature and obtaining the assistance of a clinical advisory panel, a list of potential clinical risk factors for death after AMI was developed. These potential clinical risk factors are listed in Table 2.1 of the 1997 *Technical Guide.*

This report employs the same risk factors included in the 1997 *Technical Guide*. In previous years, all risk-adjustment models were carefully reviewed with

members of the AMI clinical advisory panel and outside consultants. The advisory panel included several cardiologists, one nurse researcher, and one coding professional with specialized expertise in the topic. They advised project staff about whether the models included appropriate covariates and whether the parameter estimates were consistent with previous research and experience in the field. The advisory panel was not reconvened for this report because the risk-adjustment procedure was thoroughly refined and validated in 1995 and 1996. Therefore, this report uses the same models and risk factors, updated only to account for minor changes in some variable definitions.

Timing of Clinical Risk Factors

The timing of diagnoses is a critical issue in risk-adjusting hospital outcomes. Any acute or chronic condition diagnosed either at or before admission may be used in risk-adjustment because it reflects severity-of-illness at admission. Any chronic condition diagnosed after admission may also be used in risk-adjustment because it was presumably present, albeit undetected, at admission. By contrast, acute conditions diagnosed after admission are problematic because they may reflect quality of care. Some complications of AMI are potentially preventable with prompt and aggressive treatment, including aspirin, thrombolytic agents, and coronary revascularization if necessary. If one treats these conditions as risk factors by including them in risk-adjustment models, one may inappropriately give hospitals credit (i.e. reduce their risk-adjusted outcome rates) when they fail to prevent complications.

Before 1996, California hospital discharge abstracts did not include any information on the timing of diagnoses. Therefore, any acute condition could be either a comorbidity (e.g., present at admission) or a complication of care (e.g., present only after admission).

This dilemma was resolved by developing two different models to adjust for differences in patient characteristics across hospitals. **Model A** is a more conservative model that includes fewer risk factors; **Model B** is a more comprehensive model that includes several additional risk factors. The risk factors in Model A almost certainly represent comorbidities - clinical or personal characteristics that were present when the patient entered the hospital.

Model B includes all of the risk factors in Model A plus certain demographic variables (e.g., race, source of admission, expected principal source of payment) and clinical characteristics with unclear timing (e.g., shock, pulmonary edema). By comparing the results from Models A and B, one can assess the sensitivity of hospital-specific risk-adjusted mortality rates to assumptions about the timing of acute conditions. The development of these models is further described in Section 7.

The presence or absence of each risk factor was determined after linking serial hospitalizations for AMI patients who were transferred from one hospital to another. The discharge diagnoses from all hospitals involved in the episode of care were combined into a single list. Thus, a patient who was transferred from Hospital X to Hospital Y but only had hypertension coded in Hospital Y was

classified as hypertensive in the analysis of Hospital X's AMI outcomes. Hospitals thereby received credit for clinical risk factors that they might not have had the opportunity to discover or document before transfer. Many inter-hospital transfers occur so quickly that the initial hospital cannot complete its diagnostic evaluation.

During the 6 months before the date of an index AMI admission, 17.0% of cases had one or more prior hospitalizations. Among these cases, prior discharge abstracts provided additional information about the presence and timing of clinical risk factors. If a diagnosis was noted on a prior discharge abstract, then it clearly preceded the AMI of interest. For this reason, clinical risk factors were defined somewhat differently according to whether there were any prior hospitalizations. The impact of prior admissions on the definition of clinical risk factors is described in detail in Chapter Seven of the 1997 *Technical Guide.*

Definitions of Clinical Risk Factors

Table 6.3 shows the definitions of all clinical risk factors used in any of the final risk-adjustment models for AMI mortality. Table 6.4 shows the prevalence of these risk factors in the sample of patients with one or more prior admissions. Table 6.5 shows the prevalence of these risk factors in the sample of patients with no prior admissions.

Table 6.1: Demographic characteristics of acute myocardial infarction cases (after exclusions)

	1996		*1997*		*1998*	
Characteristic	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Total	43,400		43,702		41,405	
Gender						
Male	27,248	62.8	27,121	62.1	25,645	61.9
Female	16,152	37.2	16,581	37.9	15,760	38.1
Race/Ethnicity						
White	32,493	74.9	32,517	74.4	30,137	72.8
Latino	4,839	11.1	4,937	11.3	5,019	12.1
African American	2,638	6.1	2,538	5.8	2,460	5.9
Asian/Pacific Islander	2,339	5.4	2,512	5.7	2,546	6.1
Native American	94	0.2	96	0.2	66	0.2
Other	664	1.5	781	1.8	836	2.0
Missing/Unknown	333	0.8	321	0.7	341	0.8
Age						
Mean	67.7		68.1		68.5	
Standard Deviation	13.5		13.6		13.7	

Table 6.2: Hospitalization characteristics of acute myocardial infarction cases (after exclusions).

	1996		1997		1998	
Characteristic	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Total	43,400	100.00	43,702	100.0	41,405	100.0
Admission Type						
Scheduled	806	1.9	645	1.5	569	1.4
Unscheduled	42,549	98.0	43,052	98.5	40,823	98.6
Missing/unknown	45	0.1	5	0.0	13	0.0
Admission Source – Level of Care						
Home	42,656	98.3	42,916	98.2	40,506	97.8
Residential Care Facility	273	0.6	284	0.6	307	0.7
Ambulatory	140	0.3	171	0.4	244	0.6
Other Inpatient	163	0.4	199	0.5	171	0.4
Prison/Jail	58	0.1	59	0.1	76	0.2
Other	110	0.3	73	0.2	101	0.2
Admission Source – Route						
Your Emergency Room[11]	37,194	85.7	37,957	86.9	36,243	87.5
Not Your Emergency Room[12]	6,206	14.3	5,745	13.1	5,162	12.5
Payment Source						
Medicare	22,555	52.0	23,290	53.3	22,393	54.1
Medi-Cal	3,063	7.1	2,774	6.3	2,568	6.2
Workers' Compensation	162	0.4	127	0.3	166	0.4
CHAMPUS/CHAMPVA/VA	191	0.4	200	0.5	171	0.4
Other Government	117	0.3	100	0.2	140	0.3
Blue Cross/Blue Shield	671	1.5	752	1.7	769	1.9
Private Insurance Company	1,899	4.4	1,720	3.9	1,502	3.6
HMO	9,003	20.7	8,923	20.4	8,362	20.2
PPO	3,456	8.0	3,560	8.1	3,244	7.8
Self-Pay	1,471	3.4	1,521	3.5	1,303	3.1
Charity[13]	107	0.2	98	0.2	115	0.3
Other Non-Government	71	0.2	30	0.1	59	0.2
County Indigent Programs[14]	633	1.5	606	1.4	605	1.5
Discharge Disposition						
Routine	21,977	50.6	22,375	51.2	20,484	49.5
Acute Hospital	10,348	23.8	10,013	22.9	10,029	24.2
Skilled Nursing Facility/Other LT	3,536	8.1	4,007	9.2	3,939	9.5
Left Against Medical Advice	400	0.9	483	1.1	419	1.0
Died[15]	4,045	9.3	4,002	9.2	3,734	9.0
Home Health	3,094	7.1	2,822	6.5	2,797	6.8

[11] Patients admitted after being examined in the reporting hospital's emergency department. This excludes patients seen in the emergency department of another hospital.
[12] Patients admitted without being seen in the reporting hospital's emergency department. This includes patients seen in the emergency department of another hospital and patients not seen in any emergency department.
[13] Combines "charity care" and "no charge" categories.
[14] Same as "medically indigent services" in 1994.
[15] Note that this represents the number of deaths identified on the OSHPD discharge records. The number of deaths in the final models reported in Section 7 was determined after matching hospital records with Vital Statistics death records, as described in Chapter Three.

Table 6.3: ICD-9-CM codes of clinical risk factors for death after acute myocardial infarction

Code	*ICD-9-CM Description*	*Source of Data**
	Aspiration pneumonia (ASPPNEUI)	Index only[1]
507.0	Aspiration pneumonia	
	Catastrophic sequelae of AMI (AMISEQUI)	Index only[1]
429.5	Rupture of chordae tendineae	
429.6	Rupture of papillary muscle	
429.71	Acquired cardiac septal defect	
745.4	Ventricular septal defect	
	Central nervous system disease (CNSDISB)	Index or prior
331.1-331.9	Other cerebral degenerations (except Alzheimer's disease)	
332.x	Parkinson's disease	
333.0	Other degenerative diseases of the basal ganglia	
333.2	Myoclonus	
333.3	Tics of organic origin	
333.4	Huntington's chorea	
333.5	Other choreas	
333.6	Idiopathic torsion dystonia	
333.7	Symptomatic torsion dystonia	
340	Multiple scierosis	
341.x	Other demyelinating diseases of central nervous system	
344.x	Other paralytic syndromes	
	Cerebrovascular disease, other (OTHCVAI)	Index only[1]
430	Subarachnoid hemorrhage	
431	Interacerebral hemorrhage	
432.x	Other and unspecified intracranial hemorrhage	
434.x	Occlusion of cerebral arteries	
436	Acute but ill-defined cerebrovascular disease	
437.1	Other generalized ischemic cerebrovascular disease	
	Coma (COMAI)	Index only[1]
780.0x	Alteration of consciousness	
250.2x	Diabetes with hyperosmolarity (hyperosmolar coma)	
250.3x	Diabetes with other coma	
572.2	Hepatic coma	
	Complete atrioventricular block (COATRBLI)	Index only[1]
426.0	Complete atrioventricular block	
	Congestive heart failure (CHFB)	Index or prior
425.x	Cardiomyopathy	
428.x	Heart failure	
	Diabetes, complicated (DBTCMPB)	Index or prior
250.1x-250.9x	Diabetes with mention of complication	
357.2	Polyneuropathy in diabetes	
362.0x	Diabetic retinopathy	
	High-risk or secondary malignant neoplasm (HRSECMAB)	Index or prior
141.x-152.x	Malignant neoplasm of oral cavity, pharynx, esophagus, stomach, small intestine	
155.x-159.x	Malignant neoplasm of liver, gall bladder, pancreas, peritoneum	
162.x-171.x	Malignant neoplasm of lung, pleura, heart, thorax, bone, connective tissue	
196.x-199.x	Second malignant neoplasm	
	Hypertension (HTB)	Index or prior[2]
401.x	Essential hypertension	
402.x0	Hypertensive heart disease	
403.x0	Hypertensive renal disease	
404.x0	Hypertensive heart and renal disease	
405.xx	Secondary hypertension	

Table 6.3: ICD-9-CM codes of clinical risk factors for death after acute myocardial infarction

Code	*ICD-9-CM Description*	*Source of Data**
	Infarction site, anterior wall (SITE_ANT)	Index only[3]
410.0x	Anterior wall	
410.1x	Other anterior wall	
410.2x	Inferolateral	
410.5x	Other lateral	
	Infarction site, inferior wall (SITE_INF)	Index only[4]
410.3x	Inferoposterior wall	
410.4x	Other inferior wall	
410.6x	Posterior wall	
	Infarction site, other (SUBENDOI)	Index only[5]
410.8x	Other unspecified sites	
410.9x	Unspecified sites	
	Infarction site, subendocardial (SUBENDOI)	Index only
410.7x	Subendocardial	
	Ischemic bowel or liver (VASINSUI)	Index only[1]
557.x	Vascular insufficiency of intestine	
570	Acute and subacute necrosis of liver	
	Paroxysmal ventricular tachycardia (PVENTACI)	Index only[1]
427.1	Paroxysmal ventricular tachycardia	
	Prior coronary artery bypass graft (PRCABG)	
996.03	Mechanical complication due to coronary bypass graft	Index or prior[6]
V45.81	Aortocoronary bypass status	Index or prior[7]
36.1x	Bypass anastomosis for heart revascularization	Prior only
	Pulmonary edema (PULEDEMI)	Index only[1]
514	Pulmonary congestion and hypostasis	
518.4	Acute edema of lung, unspecified	
518.5	Pulmonary insufficiency following trauma and surgery	
518.81	Respiratory failure	
518.82	Other pulmonary insufficiency, not elsewhere classified	
	Renal Failure, acute or unspecified (ACRENALI)	Index only[1,8]
584.x	Acute renal failure	
586	Renal failure, unspecified	
788.5	Oliguria and anuria	
	Renal failure, chronic (CHRRENAB)	
585	Chronic renal failure	Index or prior
403.x1	Hypertensive renal disease (malignant, benign, or unspecified), with renal failure	Index or prior
404.x2	Hypertensive heart and renal disease (malignant, benign, or unspecified), with renal failure	Index or prior
404.x3	Hypertensive heart and renal disease (malignant, benign, or unspecified), with congestive heart and renal failure	Index or prior
996.73	Other complications due to renal dialysis device, implant, and graft	Index or prior[9]
39.27	Arteriovenostomy for renal dialysis	Prior only
39.42	Revision of arteriovenous shunt for renal dialysis	Index or prior[10]
39.93	Insertion of vessel-to-vessel cannula	Prior only
39.94	Replacement of vessel-to-vessel cannula	Index or prior[1]
V45.1	Renal dialysis status	
	Seizure disorder (EPILEPB)	Index or prior[1]
345.xx	Epilepsy	
780.3	Convulsions	
	Sepsis (SEPSISI)	Index only[11]
038.xx	Sepsis	
112.5	Disseminated candidiasis	
	Shock (SHOCKI)	Index only[1]
785.5x	Shock without mention of trauma	
	Skin ulcer (SKNULCRP)	Prior only

Table 6.3: ICD-9-CM codes of clinical risk factors for death after acute myocardial infarction

Code	*ICD-9-CM Description*	*Source of Data**
707.x	Chronic skin ulcer	
	Thyroid disease (THYROIDB)	Index or prior
243.x-244.x	Hypothyroidism	

Table 6.4: Clinical characteristics of AMI cases with one or more prior admissions (N=21,763)*

Characteristic	*Number*	*Percent*
Aspiration Pneumonia (ASPPNEUI)	38	1.8
Central Nervous System Disease (CNSDISB)	617	2.8
Cerebrovascular Disease, Other (OTHCVAI)	518	2.4
Coma (COMA)	336	1.5
Congestive Heart Failure (CHFB)	11,573	53.2
Diabetes, Complicated (DBTCMPB)	3,550	16.3
High-Risk or Secondary Malignant Neoplasm (HRSECMAB)	810	3.7
Hypertension (HTB)	11,520	52.9
Infarction Site, Anterior Wall (SITE_ANT)	4,995	23.0
Infarction Site, Interior Wall (SITE_INF)	3,435	15.8
Infarction Site, Other (SITE_OI)	2,206	10.1
Paroxysmal Ventricular Tachycardia (PVENTACI)	1,531	7.0
Prior Coronary Artery Bypass Graft (PRCABG)	518	2.4
Pulmonary Edema (PULEDEMI)	2,047	9.4
Renal Failure, Acute or Unspecified (ARENALI)	1,508	6.9
Renal Failure, Chronic (CHRRENAB)	3,177	14.6
Seizure Disorder (EPILEPB)	530	2.4
Sepsis (SEPSIS)	682	3.1
Shock (SHOCKI)	1,312	6.0
Skin Ulcer (SKNULCRP)	697	3.2

* Characteristics in this table were ascertained from either index admissions or prior admissions or both, as noted in Table 6.3. Only variables included in either of the final risk-adjustment models are shown.

Table 6.5: Clinical characteristics of AMI cases with no prior admissions (N=106,746)*

Characteristic	*Number*	*Percent*
AMI Sequela (AMISEQUI)	243	0.2
Aspiration Pneumonia (ASPPNEUI)	1,572	1.5
Central Nervous System Disease (CNSDISB)	1,322	1.2
Cerebrovascular Disease, Other (OTHCVAI)	2,103	2.0
Coma (COMAI)	1,136	1.1
Complete Atrioventricular Block (COATRBLI)	2,649	2.5
Congestive Heart Failure (CHFB)	30,031	28.1
Diabetes, Complicated (DBTCMPB)	5,440	5.1
High-Risk Malignant Neoplasm (HRSECMAB)	838	0.8
Hypertension (HTB)	48,610	45.5
Infarction Site, Anterior Wall (SITE_ANT)	31,727	29.7
Infarction Site, Inferior Wall (SITE_INF)	26,590	24.9
Infarction Site, Other (SITE_OI)	6,101	5.7
Ischemic Bowel or Liver Disease (VASINSUI)	304	0.3
Paroxysmal Ventricular Tachycardia (PVENTACI)	8,162	7.6
Prior Coronary Artery Bypass Graft (PRCABG)	13	0.0
Pulmonary Edema (PULEDEMI)	7,152	6.7
Renal Failure, Acute or Unspecified (ACRENALI)	4,414	4.1
Renal Failure, Chronic (CHRRENAB)	3,833	3.6
Seizure Disorder (EPILEPB)	1,150	1.1
Shock (SHOCKI)	5,457	5.1
Thyroid Disease (THYROIDB)	6,430	6.0

* Characteristics in this table were ascertained from either index admissions or prior admissions or both, as noted in Table 6.3. Only variables included in either of the final risk-adjustment models are shown.

Section 7

Presentation and Interpretation of Final Models

In this Section, the final risk-adjustment models are presented. These models represent a best effort to elucidate the relationship between AMI mortality and various demographic and clinical risk factors.

The Four Models

The risk-adjustment models for AMI mortality were classified according to whether one or more hospitalizations occurred during the 8 weeks before the index admission. If there were prior hospitalizations, then more information about possible comorbidities was available. For example, cerebrovascular disease could be used as a risk factor in Model A if it was diagnosed during a prior hospitalization. If no records from prior hospitalizations were available, cerebrovascular disease could not be used as a risk factor in Model A because it could have represented an in-hospital complication of the AMI. Overall, 21,763 (16.9%) of the 128,509 study cases had one or more prior hospitalizations.

Table 7.1 shows the AMI Model A parameters for cases with no prior admissions; Table 7.2 shows the Model A parameters for cases with one or more prior admissions. Table 7.3 shows the Model B parameters for cases with no prior admissions; Table 7.4 shows the Model B parameters for cases with one or more prior admissions. Each risk variable in these tables is defined in Section 6. The columns in these tables are explained in the Technical Appendix to this Section.

Table 7.1 shows that the following factors were associated with a significantly **increased** risk of death among AMI cases **without** prior hospitalizations: female gender, other or unspecified infarction site, anterior wall infarction, congestive heart failure (CHF), high-risk or metastatic malignancy, complicated diabetes, chronic kidney failure, and central nervous system disease. Uncomplicated hypertension and hypothyroidism were associated with a significantly **decreased** risk of death among these AMI cases. The relationship between age and mortality followed a U-shaped function, with decreasing risk of death up to 35 years of age and increasing risk of death above that age. AMIs in 1998 had a slightly greater risk of dying than those AMIs in 1996 or 1997, but the differences were not statistically significant.

The interaction terms reveal that the independent effect of CHF on mortality decreased with age (reaching zero at 122 years of age) and also decreased by varying amounts with infarction site. In addition, the impact of CHF was greater among men than among women. The incremental risk associated with female gender and other or unspecified infarction site declined with age, whereas the incremental risk associated with inferior infarction site increased with age. The

interactions of CHF with anterior wall infarction site, inferior wall site, other infarction site, and female sex were also statistically significant and associated with a decreased risk of mortality.

Table 7.2 shows that the following factors were associated with a significantly **increased** risk of death among AMI cases **with** prior hospitalizations: female gender, age, CHF, high-risk or metastatic malignancy, complicated diabetes, chronic kidney failure, prior skin ulcer, anterior wall infarction site, inferior wall infarction site, and other or unspecified infarction site. Uncomplicated hypertension, and number of weeks from most recent prior admission were associated with a significantly **decreased** risk of death among these AMI cases. Relative to AMIs in 1998, those in 1996 and 1997 had a slightly higher risk of death, although this effect was not statistically significant in either year.

The interaction terms reveal that the effect of CHF on mortality decreased with age (reaching zero at 118 years of age). The impact of CHF was greater among men than among women, and when infarction site was not specified. This model includes fewer predictors than the model in Table 7.1 because of its smaller sample size.

In addition to the factors identified in Model A, the following risk factors in Model B were associated with a significantly **increased** risk of death among AMI cases **without** prior hospitalizations (Table 7.3): pulmonary edema, shock, other cerebrovascular disease, coma, aspiration pneumonia, acute kidney failure, complete atrioventricular block, ischemic bowel or liver disease, catastrophic sequelae of AMI, seizure disorder, and paroxysmal ventricular tachycardia. Medi-Cal patients and uninsured patients also had a higher risk of death than others. African American patients had lower risk of death than white and Latino patients.

Among AMI cases with shock, other risk factors such as CHF, aspiration pneumonia, cerebrovascular disease, pulmonary edema, complete atrioventricular block, ventricular tachycardia, and catastrophic AMI sequelae had the combined effect of reducing mortality risk. Coma combined with age, CHF or pulmonary edema was associated with a decreased mortality risk. CHF combined with pulmonary edema was also associated with a decreased risk of death.

In addition to the factors identified in Model A, the following risk factors in Model B were associated with a significantly **increased** risk of death among AMI cases **with** prior hospitalizations (Table 7.4): prior coronary artery bypass graft (CABG), pulmonary edema, shock, other cerebrovascular disease, coma, aspiration pneumonia, acute kidney failure, paroxysmal ventricular tachycardia, sepsis, and seizure disorder. Uninsured patients also had a higher risk of death than others. The interactions of shock with aspiration pneumonia, CHF, pulmonary edema, and other cardiovascular disease each reduced the risk of death.

For both Model B without prior admissions and Model A without prior admission, Coronary Artery Bypass Graft (CABG) and its interaction with Congestive Heart

Failure (CHF) did not result in statistically significant parameter estimates. Because the number of heart attacks with a history of CABG was small, the models in Tables 7.1 and 7.3 produced odds ratios that were extremely small (<0.001) or large (>999.99). As can be seen in the previous Section's Table 6.5, only 13 of the cases without prior admissions had undergone a CABG. This is a dramatic decrease from earlier outcomes reports, where (for cases without prior admissions) 7,159 CABGs were reported between 1991-1993, and 464 CABGs were reported between 1994-1996. Further analyses (not reported in this volume) determined that eliminating CABG and its interaction with CHF from the two models without prior admissions would not change the parameter estimates of the remaining predictors as reported in Table 7.1 and 7.3. In other words, for cases without prior admissions, the contribution of CABG to the risk-adjustment is negligible.

Table 7.1: Acute myocardial infarction 30-day mortality Model A, cases with no prior admissions (N=106,744).

*Variable**	*Parameter Estimate*	*p-value*	*Lower CL*	*Odds Ratio*	*Upper CL*
Intercept	-8.0722	0.0001			
Female	1.0904	0.0001	2.25	2.98	3.94
Age (in years)	0.0680	0.0001	1.07	1.07	1.07
Age <35	0.1336	0.0001	1.08	1.14	1.22
1996 Admission	0.0237	0.3573	0.97	1.02	1.08
1997 Admission	-0.0112	0.6657	0.94	0.99	1.04
Congestive Heart Failure (CHF)	2.8509	0.0001	12.88	17.30	23.26
Chronic Renal Disease	0.5660	0.0001	1.61	1.76	1.92
Central Nervous System Disease	0.3617	0.0001	1.24	1.44	1.66
Diabetes, Complicated	0.2900	0.0001	1.23	1.34	1.45
High-Risk Malignant Neoplasm	0.9380	0.0001	2.17	2.55	3.00
Hypertension	-0.3546	0.0001	0.67	0.70	0.73
Prior Coronary Artery Bypass Graft (CABG)	-7.9378	0.8967	**	**	***
Anterior Wall Infarction	1.2846	0.0001	3.35	3.61	3.89
Inferior Wall Infarction	0.0069	0.9692	0.71	1.01	1.43
Other Infarction Site	3.3755	0.0001	19.48	29.24	43.89
Thyroid Disease	-0.2468	0.0001	0.72	0.78	0.85
Age*CHF	-0.0233	0.0001	0.97	0.98	0.98
Age*Female	-0.0108	0.0001	0.99	0.99	0.99
Age*Inferior Wall	0.0124	0.0001	1.01	1.01	1.02
Age*Other Infarction Site	-0.0188	0.0001	0.98	0.98	0.99
CHF*Anterior Wall	-0.4570	0.0001	0.57	0.63	0.70
CHF*Prior CABG	9.0417	0.8821	**	***	***
CHF*Female	-0.3421	0.0001	0.65	0.71	0.77
CHF*Inferior Wall	-0.3203	0.0001	0.64	0.73	0.82
CHF*Other Infarction Site	-0.7513	0.0001	0.41	0.47	0.54

*For the full name and ICD-9-CM description of each clinical variable, see Table 6.3.
CL = Confidence Limit (95%).
Interaction effects between two variables are denoted by '*' between two variable names in the list of variables.
** Odds Ratio < .001
*** Odds Ratio . 999.99

Table 7.2: Acute myocardial infarction 30-day mortality Model A, cases with one or more prior admissions (N=21,760).

*Variable**	*Parameter Estimate*	*p-value*	*Lower CL*	*Odds Ratio*	*Upper CL*
Intercept	-6.1132	0.0001			
Female	0.1372	0.0309	1.01	1.15	1.30
Age (in years)	0.0501	0.0001	1.05	1.05	1.06
1996 Admission	-0.0395	0.3913	0.88	0.96	1.05
1997 Admission	-0.0058	0.8985	0.91	0.99	1.09
Weeks from Most Recent Prior Admission	-0.0210	0.0001	0.97	0.98	0.98
Congestive Heart Failure (CHF)	1.9419	0.0001	4.14	6.97	11.73
Chronic Renal Disease	0.4767	0.0001	1.44	1.61	1.80
Central Nervous System Disease	0.1621	0.1170	0.96	1.18	1.44
Diabetes, Complicated	0.1062	0.0501	1.00	1.11	1.24
High-Risk Malignant Neoplasm	0.8505	0.0001	1.99	2.34	2.75
Hypertension	-0.2040	0.0001	0.75	0.82	0.88
Prior Coronary Artery Bypass Graft (CABG)	-0.2645	0.0701	0.58	0.77	1.02
Anterior Wall Infarction	1.0334	0.0001	2.56	2.81	3.08
Inferior Wall Infarction	0.9494	0.0001	2.32	2.58	2.88
Other Infarction Site	1.8814	0.0001	5.49	6.56	7.85
Prior Chronic Skin Ulcer	0.4753	0.0001	1.34	1.61	1.93
Age*CHF	-0.0165	0.0001	0.98	0.98	0.99
CHF*Female	-0.2010	0.0108	0.70	0.82	0.95
CHF*Other Infarction Site	-0.4837	0.0001	0.50	0.62	0.76

*For the full name and ICD-9-CM description of each clinical variable, see Table 6.3.
CL = Confidence Limit (95%).
Interaction effects between two variables are denoted by '*' between two variable names in the list of variables.

Table 7.3: Acute myocardial infarction 30-day mortality Model B, cases with no prior admissions (N=105,676).

*Variable**	*Parameter Estimate*	*p-value*	*Lower CL*	*Odds Ratio*	*Upper CL*
Intercept	-8.0722	0.0001			
Female (A)	1.0904	0.0001	1.82	2.49	3.40
Age (in years) (A)	0.0629	0.0001	1.07	1.07	1.08
Age <35 (A)	0.1346	0.0004	1.06	1.14	1.23
African American	-0.1917	0.0007	0.74	0.83	0.92
Latino	0.0026	0.9684	0.88	1.00	1.14
Medi-Cal	0.1150	0.0260	1.01	1.12	1.24
Uninsured	0.2384	0.0004	1.11	1.27	1.45
1996 Admission (A)	0.0260	0.3602	0.97	1.03	1.09
1997 Admission (A)	-0.0337	0.2359	0.91	0.97	1.02
Acute Renal Disease	1.4357	0.0001	3.60	4.20	4.91
Catastrophic Sequelae of AMI	1.1739	0.0001	2.07	3.24	5.06
Aspiration Pneumonia	0.9330	0.0001	2.12	2.54	3.05
Emergency Admission	0.1232	0.2274	0.93	1.13	1.38
Congestive Heart Failure (CHF) (A)	2.0107	0.0001	5.33	7.47	10.47
Chronic Renal Disease (A)	0.6556	0.0001	1.75	1.93	2.12
Central Nervous System Disease (A)	0.2722	0.0008	1.12	1.31	1.54
Complete Atrioventricular Block	0.7567	0.0001	1.87	2.13	2.44
Coma	6.3490	0.0001	260.67	571.92	***
Diabetes, Complicated (A)	0.0900	0.0612	1.00	1.09	1.20
Seizure Disorder	2.2026	0.0001	3.62	9.05	22.63
High-Risk Malignant Neoplasm (A)	1.0029	0.0001	2.29	2.73	3.25
Hypertension (A)	-0.2625	0.0001	0.73	0.77	0.81
Other Cerebrovascular Disease	1.3733	0.0001	3.51	3.95	4.44
Prior Coronary Artery Bypass Graft (CABG) (A)	-7.8550	0.9218	**	**	***
Pulmonary Edema	1.7309	0.0001	5.02	5.65	6.35
Paroxysmal Ventricular Tachycardia	0.4122	0.0001	1.39	1.51	1.64
Shock	2.8293	0.0001	15.12	16.93	18.96
Anterior Wall Infarction (A)	1.1140	0.0001	2.80	3.05	3.31
Inferior Wall Infarction (A)	-0.2432	0.2212	0.53	0.78	1.16
Other Infarction Site (A)	3.0882	0.0001	13.81	21.94	34.84
Thyroid Disease (A)	-0.2079	0.0001	0.74	0.81	0.89
Ischemic Bowel or Liver Disease	0.9938	0.0001	2.04	2.70	3.58
Acute Renal Failure*CHF	-0.3032	0.0009	0.62	0.74	0.88
Acute Renal Failure*Other Cerebrovascular Disease	-0.7292	0.0001	0.34	0.48	0.69
Age*CHF (A)	-0.0140	0.0001	0.98	0.99	0.99
Age*Female (A)	-0.0088	0.0001	0.99	0.99	1.00
Age*Inferior Wall (A)	0.0130	0.0001	1.01	1.01	1.02
Age*Other Infarction Site (A)	-0.0164	0.0001	0.98	0.98	0.99
Age*Seizure Disorder	-0.0177	0.0069	0.97	0.98	1.00
CHF*Anterior Wall (A)	-0.4682	0.0001	0.56	0.63	0.70
CHF*Inferior Wall (A)	-0.4173	0.0001	0.58	0.66	0.75
CHF*Other Infarction Site (A)	-0.7869	0.0001	0.39	0.46	0.53
CHF *Prior CABG (A)	9.1669	0.9089	**	***	***
CHF*Female (A)	-0.3094	0.0001	0.67	0.73	0.81
Complete Atrioventricular Block*Paroxysmal Ventricular Tachcardia	-0.2118	0.1672	0.60	0.81	1.09
Coma*Age	-0.0526	0.0001	0.94	0.95	0.96
Coma*Aspiration Pneumonia	-0.7755	0.0002	0.30	0.46	0.70

Table 7.3: Acute myocardial infarction 30-day mortality Model B, cases with no prior admissions (N=105,676).

*Variable**	*Parameter Estimate*	*p-value*	*Lower CL*	*Odds Ratio*	*Upper CL*
Coma*CHF	-0.5892	0.0001	0.42	0.56	0.73
Coma*Seizure Disorder	-0.1648	0.5629	0.49	0.85	1.48
Coma*Other Cerebrovascular Disease	-0.5814	0.0039	0.38	0.56	0.83
Coma*Pulmonary Edema	-0.8815	0.0001	0.31	0.41	0.56
Pulmonary Edema*Anterior Wall	-0.1747	0.0076	0.74	0.84	0.96
Pulmonary Edema*Aspiration Pneumonia	-0.3857	0.0021	0.53	0.68	0.87
Pulmonary Edema*CHF	-0.7682	0.0001	0.41	0.46	0.53
Shock*Acute Renal Failure	-0.2279	0.0188	0.66	0.80	0.96
Shock*Catastrophic Sequelae of AMI	-0.9816	0.0014	0.21	0.38	0.68
Shock*Aspiration Pneumonia	-1.3608	0.0001	0.19	0.26	0.34
Shock*CHF	-0.6720	0.0001	0.44	0.51	0.59
Shock*Complete Atrioventricular Block	-0.9846	0.0001	0.30	0.37	0.47
Shock*Coma	-0.4848	0.0331	0.39	0.62	0.96
Shock*Other Cerebrovascular Disease	-1.0244	0.0001	0.25	0.36	0.51
Shock*Pulmonary Edema	-1.1669	0.0001	0.27	0.31	0.36
Shock*Paroxysmal Ventricular Tachycardia	-0.3000	0.0008	0.62	0.74	0.88

* For the full name and ICD-9-CM description of each clinical variable, see Table 6.3.
CL = Confidence Limit (95%). Interaction effects between two variables are denoted by '*' between two variable names in the list of variables.
(A) = variable also appears in Model A. .
** Odds Ratio < .001
*** Odds Ratio > 999.99.

Table 7.4: Acute myocardial infarction 30-day mortality Model B, cases with one or more prior admissions (N=21,624).

*Variable**	*Parameter Estimate*	*p-value*	*Lower CL*	*Odds Ratio*	*Upper CL*
Intercept	-6.9073	0.0001			
Female (A)	0.1162	0.0911	0.98	1.12	1.29
Age (in years) (A)	0.0523	0.0001	1.05	1.05	1.06
African American	-0.1427	0.0805	0.74	0.87	1.02
Latino	0.0760	0.5016	0.86	1.08	1.35
Medi-Cal	0.0302	0.7193	0.87	1.03	1.22
Uninsured	0.4716	0.0094	1.12	1.60	2.29
1996 Admission (A)	-0.0396	0.4280	0.87	0.96	1.06
1997 Admission (A)	-0.0312	0.5239	0.88	0.97	1.07
Weeks from Most Recent Prior Admission (A)	-0.0208	0.0001	0.97	0.98	0.98
Acute Renal Disease	1.0995	0.0001	2.51	3.00	3.59
Aspiration Pneumonia	0.5952	0.0001	1.39	1.81	2.36
Emergency Admission	0.3091	0.0347	1.02	1.36	1.81
Congestive Heart Failure (CHF) (A)	1.6054	0.0001	2.81	4.98	8.82
Chronic Renal Disease (A)	0.5844	0.0001	1.60	1.79	2.02
Central Nervous System Disease (A)	0.0790	0.4832	0.87	1.08	1.35
Coma	1.7701	0.0001	4.48	5.87	7.70
Diabetes, Complicated (A)	0.0134	0.8187	0.90	1.01	1.14
Seizure Disorder	0.6868	0.0001	1.58	1.99	2.50
High-Risk Malignant Neoplasm (A)	0.9013	0.0001	2.07	2.46	2.93
Hypertension (A)	-0.1890	0.0001	0.76	0.83	0.90
Other Cerebrovascular Disease	0.8924	0.0001	1.97	2.44	3.03
Prior Coronary Artery Bypass Graft (CABG) (A)	-0.3679	0.0248	0.50	0.69	0.95
Pulmonary Edema	0.9438	0.0001	2.27	2.57	2.91
Paroxysmal Ventricular Tachycardia	0.3284	0.0001	1.21	1.39	1.60
Sepsis	0.3083	0.0059	1.09	1.36	1.69
Shock	2.6065	0.0001	10.58	13.55	17.37
Anterior Wall Infarction (A)	0.8687	0.0001	2.16	2.38	2.63
Inferior Wall Infarction (A)	0.7863	0.0001	1.95	2.20	2.47
Other Infarction Site (A)	1.7092	0.0001	4.55	5.52	6.71
Prior Chronic Skin Ulcer (A)	0.3876	0.0001	1.21	1.47	1.79
Age*CHF (A)	-0.0142	0.0002	0.98	0.99	0.99
CHF*Female (A)	-0.1386	0.1032	0.74	0.87	1.03
CHF*Shock	-0.4679	0.0013	0.47	0.63	0.83
CHF*Other Infarction Site (A)	-0.4097	0.0004	0.53	0.66	0.83
Shock*Acute Renal Failure	-0.2540	0.2025	0.52	0.78	1.15
Shock*Aspiration Pneumonia	-0.7898	0.0111	0.25	0.45	0.84
Shock*Coma	0.3027	0.6363	0.39	1.35	4.75
Shock*Other Cerebrovascular Disease	-0.9429	0.0169	0.18	0.39	0.84
Shock*Pulmonary Edema	-1.1292	0.0001	0.24	0.32	0.43
Shock*Sepsis	-0.2398	0.2846	0.51	0.79	1.22

* For the full name and ICD-9-CM description of each clinical variable, see Table 6.3.
CL = Confidence Limit (95%). Interaction effects between two variables are denoted by '*' between two variable names in the list of variables.
(A) = variable also appears in Model A.

Section 8

Testing the Internal Validity of Risk-Adjustment Models

For this study, the internal validity of a risk-adjustment model is defined as how well it controls for differences in patient characteristics that would otherwise confound outcome comparisons across hospitals. A model that does not adequately control for such differences may generate biased and misleading estimates of risk-adjusted mortality rates. The internal validity of the risk-adjustment models presented in Section 7 was assessed in three basic ways: content validity, discrimination, and calibration.

Content Validity

In previous years, all risk-adjustment models were carefully reviewed with members of the AMI clinical advisory panel and outside consultants. The advisory panel included several cardiologists, one nurse researcher, and one coding professional with specialized expertise in the topic. They advised project staff about whether the models included appropriate covariates and whether the parameter estimates were consistent with previous research and experience in the field. The advisory panel was not reconvened this year because the risk-adjustment procedure was thoroughly refined and validated in 1995 and 1996.

Discrimination

A model that distinguishes well between individuals who have poor outcomes and those who have good outcomes has excellent discrimination. A model with perfect discrimination would assign to every patient an expected probability of either zero or one. With perfect discrimination all persons with an expected probability of one, but no one with an expected probability of zero, would experience the outcome of interest. No model has perfect discrimination in the real world, but good models show substantial difference in the expected probability of the outcome (death) between those who actually experienced it and those who did not.

A commonly used measure of discrimination is the c statistic, which represents the proportion of all randomly selected pairs of observations with different outcomes (e.g., one death and one survivor)[16]. The c statistic takes on values between 0 and 1.0. A value higher than 0.5 indicates an overall pattern of discrimination in an expected direction, where patients who died had higher expected probabilities of death than survivors. A value of 0.5 can be obtained by random variation, thus indicating lack of discrimination. A value

[16] Hanley JA, McNeil BJ. The meaning and use of the area under a receiver operating characteristic (ROC) curve. Radiology 1982; 143:29-36. The c statistic is equivalent to the area under a receiver operating characteristic curve, which represents a plot of sensitivity versus 1-specificity at various cutoff values for the predicted probability.

less than 0.5 indicates discrimination in an unexpected direction where patients who died had lower expected probabilities of death than survivors. There is no widely accepted cutoff for the c statistic that distinguishes "adequate" from "inadequate" models.

Table 8.1 shows that the primary risk models for AMI mortality have c statistics of 0.774 for cases with no prior admissions and 0.738 for cases with one or more prior admissions.[17] These c statistics are based on Model A, which omitted demographic and clinical risk factors that may reflect quality of care. As expected, Model B shows greater discrimination than Model A, with c statistics of 0.855 for cases with no prior admissions and 0.810 for cases with one or more prior admissions. This difference between the results for Model A and Model B is largely attributable to two powerful predictors that were used only in Model B: shock and coma. Both predictors were omitted from Model A because they may represent either in-hospital complications or associated conditions present on admission.

A more complete discussion of how these models compare with other risk-adjustment efforts appears in Chapter 10 of the 1997 *Technical Guide*.

Calibration and Bias

Calibration is the extent that observed outcome rates correspond to predicted rates across a set of defined strata. A well-calibrated model demonstrates excellent fit across a broad range of patient characteristics. Calibration may be a more relevant measure than discrimination when the purpose of a model is to predict outcome rates for groups of persons with similar characteristics (e.g., inpatients at the same hospital). By contrast, discrimination is more important if a model is being used to predict an individual's outcome and to make treatment decisions. The most commonly used measure of calibration is Hosmer and Lemeshow's chi-squared test,[18] which compares observed with predicted outcomes across several strata (e.g., 10) that are defined by increasing levels of risk.

Table 8.1 shows that the primary risk model for AMI mortality, Model A, has non-significant Hosmer-Lemeshow statistics for cases with no prior admissions (χ^2=10.72), and for cases with one or more prior admissions (χ^2=8.91).

Model B demonstrates poorer calibration, as the Hosmer-Lemeshow chi-square statistics are 20.83 ($p<0.01$) among cases with no prior admissions and 58.00 ($p<0.001$) among cases with one or more prior admissions. These statistics are based on the complete sample. Model B has consistently poor calibration among cases with no prior admissions because it overestimates the probability of death among the lowest-risk and highest-risk patients. This problem was remedied by post hoc adjustment of the linear predictor from

[17] These statistics are based on the complete 100% sample. A stricter test of model discrimination comes from applying a regression equation estimated using 60% of the cases to the remaining 40% validation sample. This stricter test, performed in previous reports, produced results similar to those obtained with the 100% sample.
[18] Hosmer, D.W., Lemeshow S. Applied Logistic Regression. New York: John Wiley & Sons, 1989.

Model B, using a quadratic function. A complete description of this adjustment method appears in Chapter 10 of the 1997 *Technical Guide*.

The quadratic adjustment model estimated using the probability estimates from Model B produced the calibration adjustment coefficients shown in Table 8.1. The intercepts were not statistically different from zero, but the linear terms were significantly less than one, and the quadratic terms were significantly less than zero. Consequently, the estimated probability of death was adjusted slightly downward among especially low-risk and high-risk patients, but slightly upward among intermediate-risk patients. The definition of intermediate risk can be determined by solving both quadratic equations.

Adjusting the Model B probability estimates in this manner substantially improved calibration. The adjusted Hosmer Lemeshow statistics for model B were not significant for cases with one or more prior admissions (χ^2=3.88) and not significant for cases with no prior admissions (χ^2=19.54). As noted above, the Model A probability estimates did not require adjustment because the calibration of Model A was excellent. The consistent difference in calibration between Model A and Model B is probably due to multi-way interactions involving the major clinical risk factors in Model B (e.g., shock, pulmonary edema) that are complex and difficult to model.

Table 8.1: Goodness-of-fit tests for AMI mortality models

	Priors		*No Priors*	
	Model A	*Model B*	*Model A*	*Model B*
Number of cases	21,760	21,624	106,744	105,676
Number of deaths	4,007	3,953	11,528	11,427
Death rate, percent	18.41	18.43	10.80	10.81
Model chi squared	2,440	4,486	10,269	19,279
Degrees of freedom	19	40	25	63
P-value	<0.0001	<0.0001	<0.0001	<0.0001
C statistic	0.738	0.810	0.774	0.855
Calibration adjustment coefficients				
B_0 (intercept)		0.0180		-0.0161
B_1 (linear term)		0.9049		0.8676
B_2 (quadratic term)		-0.0484		-0.0456
Hosmer Lemeshow statistic[19]				
Total sample (df=8)	10.72	20.83*	8.91	58.00**
Total sample, adjusted (df=10)		3.88		19.54

* p<0.01
**p<0.001

[19] The C statistic is well-approximated by the chi-squared distribution with g-2 degrees of freedom, where g is the number of strata. However, for the adjusted model, the degrees of freedom is g. Hosmer, D.W. and Lemeshow, S. Applied Logistic Regression. New York: John Wiley & Sons, 1989, pages 141 and 170.

Section 9

Calculation of Hospital Outcome Measures

The risk-adjustment models described in Section 7 were used to calculate several hospital outcome measures. The actual values of these measures, by year and overall, are reported in the Detailed Statistical Results. The User's Guide classifies all hospitals treating AMI patients as "significantly better than expected," "significantly worse than expected," or "not significantly different than expected" based on the exact probability of the observed number of AMI deaths (or a more extreme number) at that hospital. It also includes a chart showing each hospital's risk-adjusted death rate with 98% confidence limits, based on aggregated 1994-1996 data. Each of these outcome measures is described below, along with the methods used to calculate it.

Number of Observed Deaths and Observed Death Rate

The number of observed deaths at a hospital is simply the total number of deaths within 30 days of admission, among qualifying AMI patients. The death may have occurred at the index hospital, a transfer hospital, or outside the hospital setting. The observed death rate at a hospital equals the number of observed deaths, divided by the total number of qualifying patients at that hospital. This quantity was multiplied by 100 to yield a percentage.

The distribution of observed death rates among eligible hospitals with at least one expected death is shown in Figure 9.1. The height of each bar represents the number of hospitals with observed death rates in the specified range.

Number of Expected Deaths and Expected Death Rate

The number of expected deaths at a hospital equals the sum of the estimated probabilities of death for all of its qualifying patients. These estimated probabilities were calculated using the logistic formulas in Section 7; Model B estimates were adjusted slightly to improve calibration, as described in Section 8. For example, the number of expected AMI deaths would be 5 if a hospital had 10 patients, each of whom had a 50% risk of death, or if a hospital had 100 patients, each of whom had a 5% risk of death.

The expected death rate at a hospital equals the number of expected deaths, divided by the total number of qualifying patients at that hospital. This quantity was multiplied by 100 to yield a percentage. The expected death rate also represents the mean estimated probability of death for all patients at a hospital, which is a measure of average severity of illness. If a hospital's expected death rate is higher than the statewide death rate, then patients at that hospital tend to be higher risk than the statewide average. If a hospital's expected death rate is lower than the statewide death rate, then patients at that hospital tend to be

lower risk than the statewide average. The distribution of expected death rates among eligible hospitals with at least one expected death is shown in Figure 9.2. The height of each bar represents the number of hospitals with expected death rates in the specified range.

Risk-Adjusted Death Rate

The risk-adjusted (or indirectly standardized) death rate at a hospital equals the statewide rate, multiplied by the ratio of the number of observed deaths to the number of expected deaths at that hospital:[20]

$$I_i = s\left(\frac{\sum_{j=1}^{n_i} o_j}{\sum_{j=1}^{n_i} \hat{p}_j}\right) = s\frac{O_i}{\pi_i}$$

where I_i is the indirectly standardized outcome rate for the ith hospital, s is the statewide outcome rate, o_j is the observed value of the adverse outcome (0 or 1) for the jth patient, and $\hat{p}_j$ is the estimated probability of the adverse outcome for the jth patient. The latter two variables are summed over all patients at the ith hospital.

This risk-adjusted death rate provides a basis for comparing the performance of different hospitals, because each hospital's rate is adjusted to reflect what its death rate would be if its patients were about as ill as the statewide average. The ratio of the number of observed deaths to the number of expected deaths at a hospital provides a quick assessment of that hospital's performance. For a hospital with fewer observed than expected deaths, this ratio is less than one; for a hospital with more observed than expected deaths, this ratio is greater than one.

The distribution of risk-adjusted death rates among eligible hospitals with at least one expected death is shown in Figure 9.3. The height of each bar represents the number of hospitals with risk-adjusted death rates in the specified range. The distribution of risk-adjusted death rates is tighter than the distribution of observed death rates, indicating that risk-adjustment reduces some of the apparent variability in hospital performance.

Confidence Limits for Risk-Adjusted Death Rates

The 95% and 98% confidence limits reflect the level of confidence in a hospital's risk-adjusted death rate. In general, when the upper and lower confidence limits are far apart, the estimated risk-adjusted death rate is unreliable. Assuming that the risk model is correct, there is a 95% chance that a hospital's true risk-adjusted death rate falls within the 95% confidence limits, and a 98% chance that this value falls within the 98% confidence limits. The narrower 95% confidence limits are used in the *Detailed Statistical Results*, for the benefit of individual hospitals and physician groups that wish to evaluate their own

[20] Williams RL. Measuring the effectiveness of perinatal medical care. Medical Care 1979; 17:95-110.

performance. Wider 98% confidence limits are used in the *User's Guide*, because of the large number of hospitals evaluated in the study increases the risk of mislabeling a hospital as an outlier.

These 95% and 98% confidence limits were constructed from the standard deviation of the number of observed deaths at each hospital. The methodology is documented in Chapter Eleven of the 1997 *Technical Guide*.

Exact Probability of the Number of Observed Deaths

The exact probability of the number of observed deaths (or a more extreme number) occurring by chance, given the number of expected deaths at a hospital, was used to identify the outlier hospitals labeled with stars or circles in the *User's Guide*. This approach differs from the more widely used normal approximation in that it gives better estimates for hospitals with relatively few expected deaths.[21]

If the number of observed deaths exceeded the number of expected deaths, an upper probability (p) value was computed. If the number of observed deaths was less than or equal to the number of expected deaths, a lower probability (p) value was computed.

The upper p-value for a hospital is the probability that the observed number of deaths or more occurred by chance. The upper p-value represents a "test" of whether a hospital has systematically worse outcomes than the statewide average. A very small p-value of 0.001 means that one would expect to see this many deaths or more only 1 time in 1000, by chance. This finding leads one to reject the null hypothesis that the hospital's performance is equivalent to the statewide average. A more likely explanation would be a difference in quality of care, or some other systematic factor.

The lower p-value for a hospital is the probability that the observed number of deaths or fewer occurred by chance. The lower p-value represents a "test" of whether a hospital has systematically better outcomes than the statewide average. A very small p-value again leads one to reject the null hypothesis that the hospital's performance is equivalent to the statewide average.

The classification of hospitals' AMI death rates as "significantly better than expected," "significantly worse than expected," or "not significantly different than expected" in the *User's Guide* was based on a p-value threshold of 0.01. Hospitals classified as significantly better than expected had fewer deaths than expected and a lower p-value less than 0.01. Hospitals classified as significantly worse than expected had more deaths than expected and an upper p-value less than 0.01.

This report includes 398 eligible hospitals that contributed one or more years of data. Using Model A, 26 of these hospitals were classified as "significantly

[21] Luft HS, Brown BW Jr. Calculating the probability of rare events: Why settle for an approximation? Health Services Research 1993; 28:419-439.

better than expected" and 36 were classified as "significantly worse than expected" based on their AMI mortality from 1996 through 1998. Using Model B, 20 hospitals were classified as "significantly better than expected" and 27 were classified as "significantly worse than expected" based on their AMI mortality from 1996 through 1998. Fourteen hospitals were rated "significantly better than expected" using both models; 12 achieved this rating using only Model A and six achieved this rating using only Model B. Twenty-one hospitals were rated "significantly worse than expected" using both models; 15 achieved this rating using only Model A and six achieved this rating using only Model B.

Figure 9.1: Distribution of Observed Death Rates Across California Hospitals

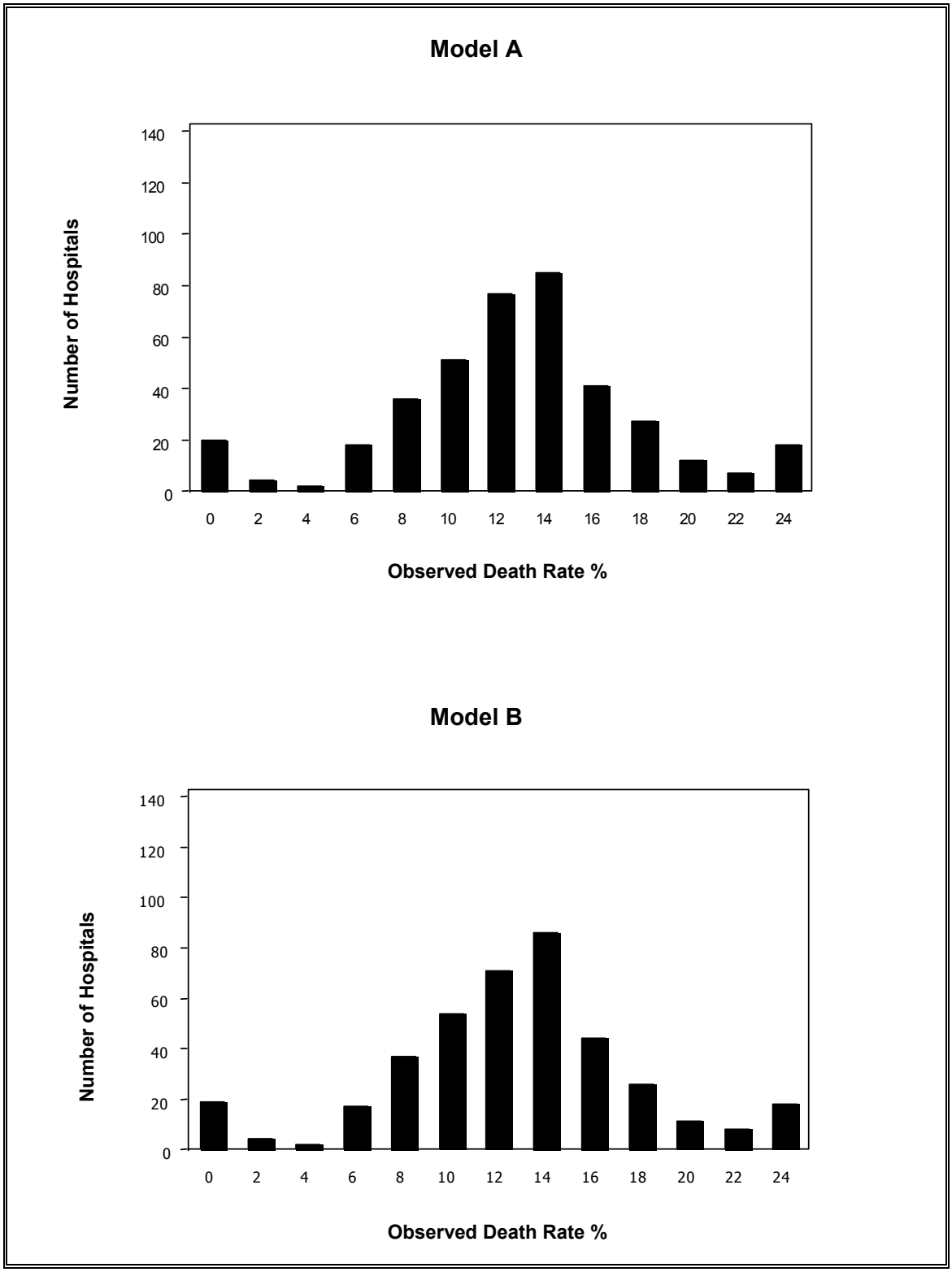


Figure 9.2: Distribution of Expected Death Rates Across California Hospitals

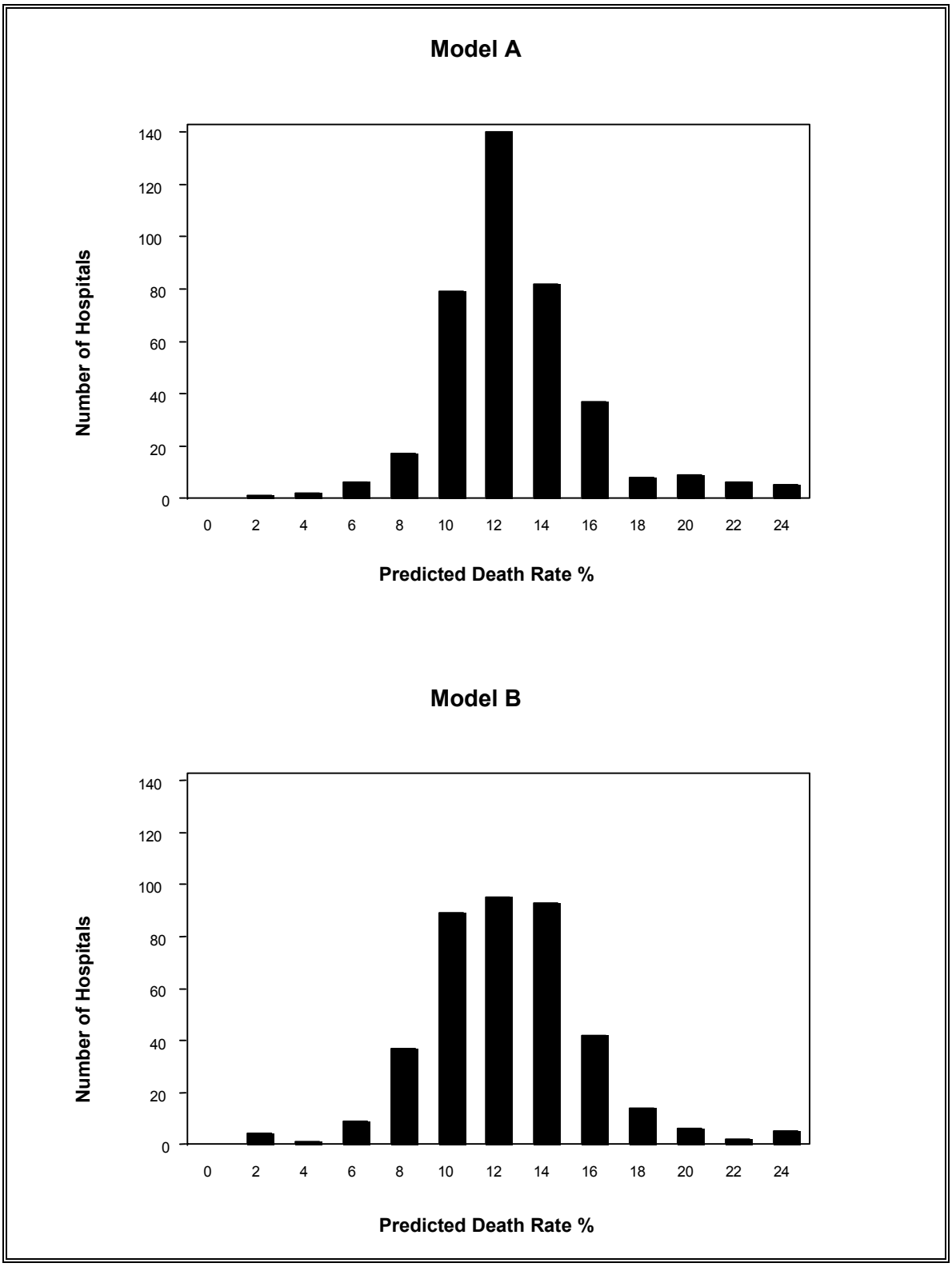
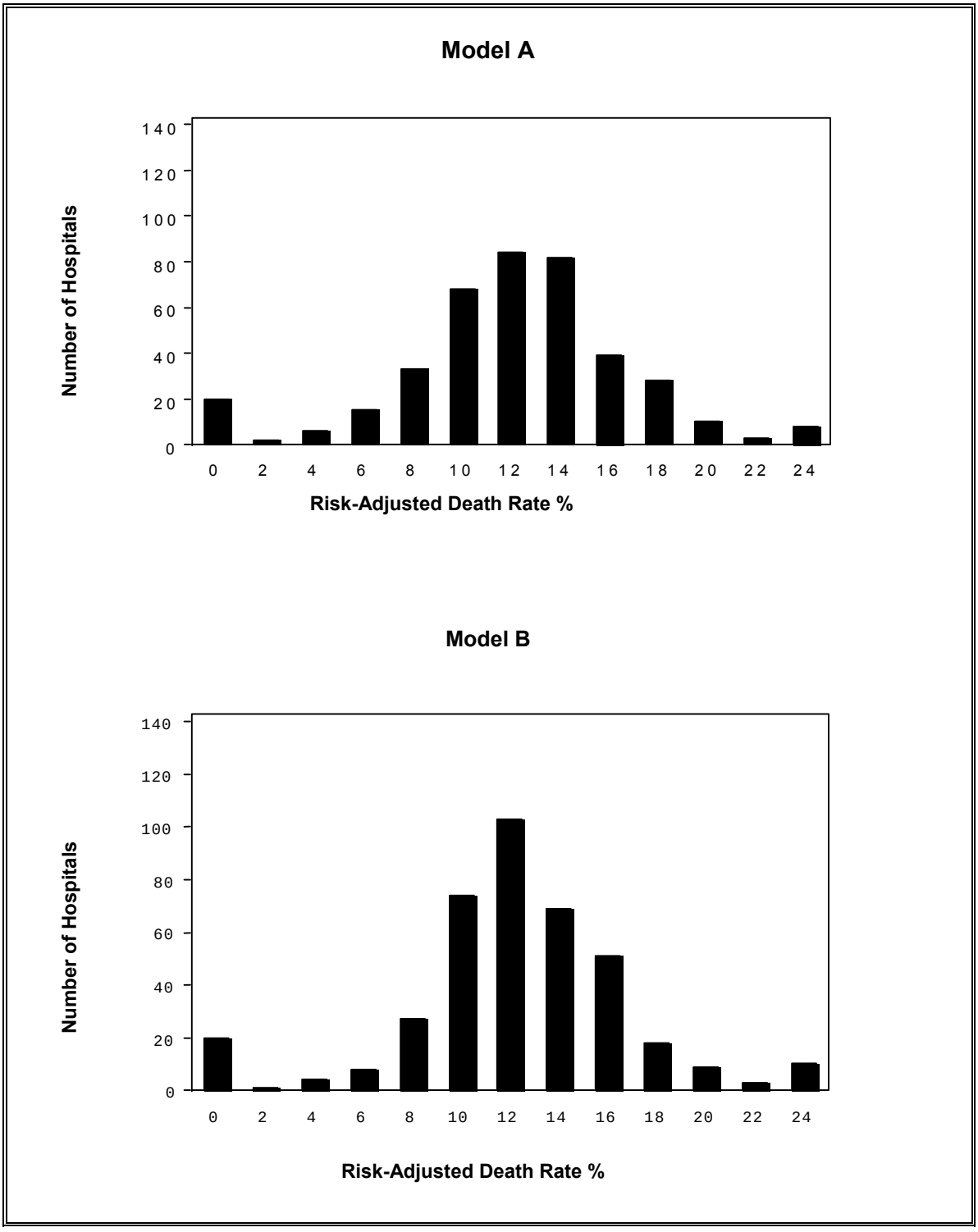


Figure 9.3: Distribution of Risk Adjusted Death Rates Across California Hospitals



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TECHNICAL APPENDIX

This appendix includes a brief description of the information displayed in each column in Tables 7.1-7.4. A more complete description of the underlying statistical principles appears in Chapter Nine of the 1997 *Technical Guide*.

1. **The parameter estimate** is a measure of the risk associated with a covariate. A negative parameter estimate indicates that the covariate has a protective effect (reduces risk); a positive parameter estimate indicates that the covariate has a harmful effect (increases risk). The further this parameter estimate is from zero, the greater the impact of this covariate on the risk of AMI death. These numbers are maximum likelihood estimates, meaning that they are more consistent with the observed data than any other possible set of parameter estimates.

2. **The p-value** is a measure of the statistical significance of a parameter estimate. A small p-value (less than 0.05) indicates that the observed parameter is significantly different from zero.

3. **The estimated odds ratio** associated with a covariate is another measure of risk, which may be easier to interpret than the parameter estimate. It equals the odds of death ($\hat{p}/[1-\hat{p}]$, where $\hat{p}$ is the probability of death) among patients with a risk factor, divided by the odds of death among patients without that characteristic, adjusted for all of the other factors in the model. When the outcome is relatively infrequent, this odds ratio approximates the relative risk. An odds ratio less than one indicates that the covariate has a protective effect; an odds ratio greater than one indicates that the covariate has a harmful effect.

   Note that the odds ratio for age, which is a continuously distributed variable, must be interpreted differently from odds ratios based on dichotomous variables. In this case, the estimated odds ratio represents the odds of death among patients of a certain age, divided by the odds of death among patients who are one year younger. The odds ratio associated with a ten-year age difference can be computed by raising the one-year odds ratio to the tenth power.

4. **The upper and lower confidence limits for the odds ratio** are an expression of confidence in the estimated odds ratio. There is a 95% probability that the true value of the odds ratio is between the lower confidence limit and the upper confidence limit. If the interval between these confidence limits includes one, then the null hypothesis that the covariate has no effect on the outcome cannot be rejected.